ROCKY FLATS PLANT
(Environmental Technology Site)
Bounded by Indiana St. & Rts. 93, 128 & 72
Golden vicinity
Jefferson County
Colorado

HAER No. CO-83

PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

REDUCED COPIES OF MEASURED DRAWINGS

HISTORIC AMERICAN ENGINEERING RECORD
INTERMOUNTAIN SUPPORT OFFICE - DENVER
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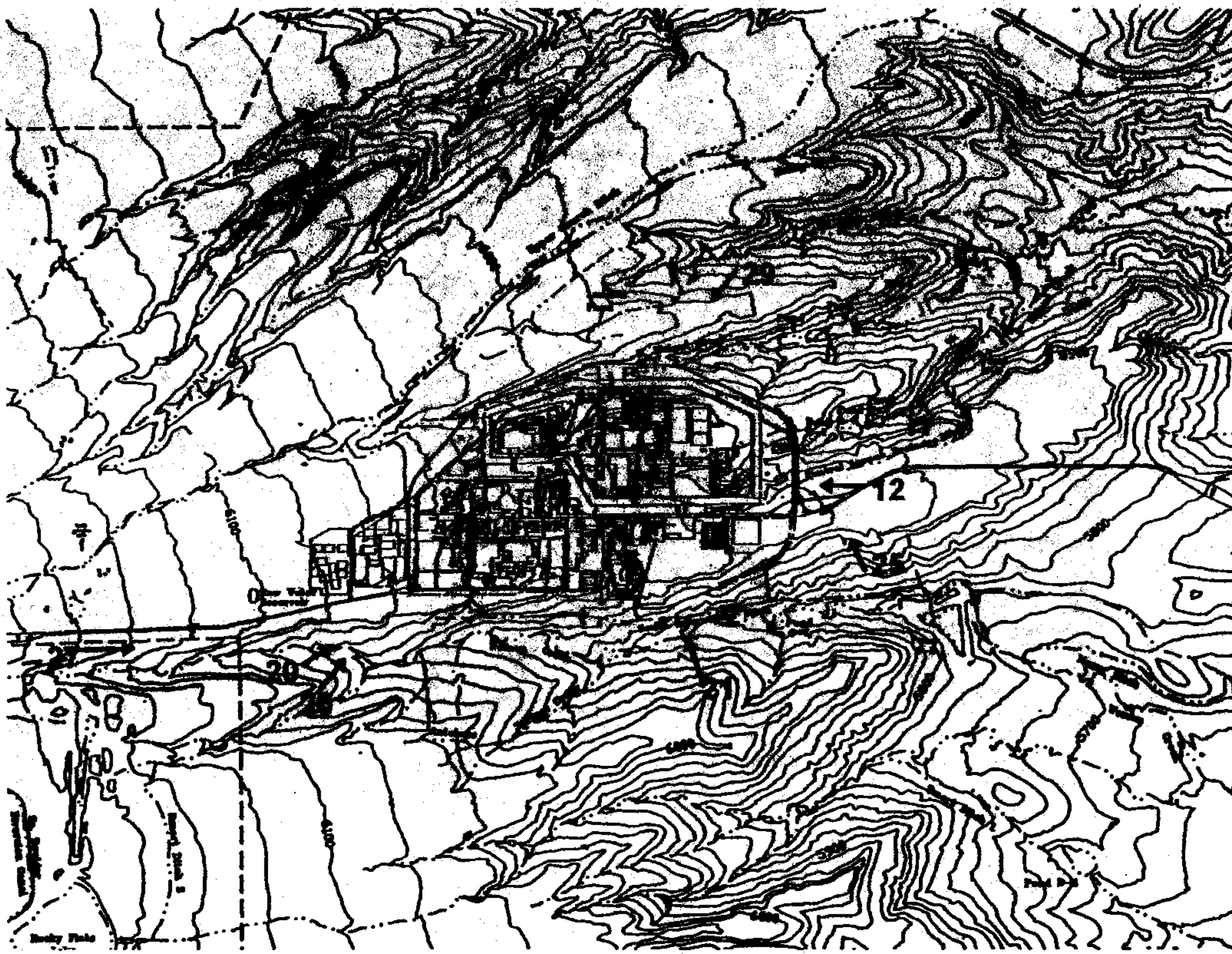

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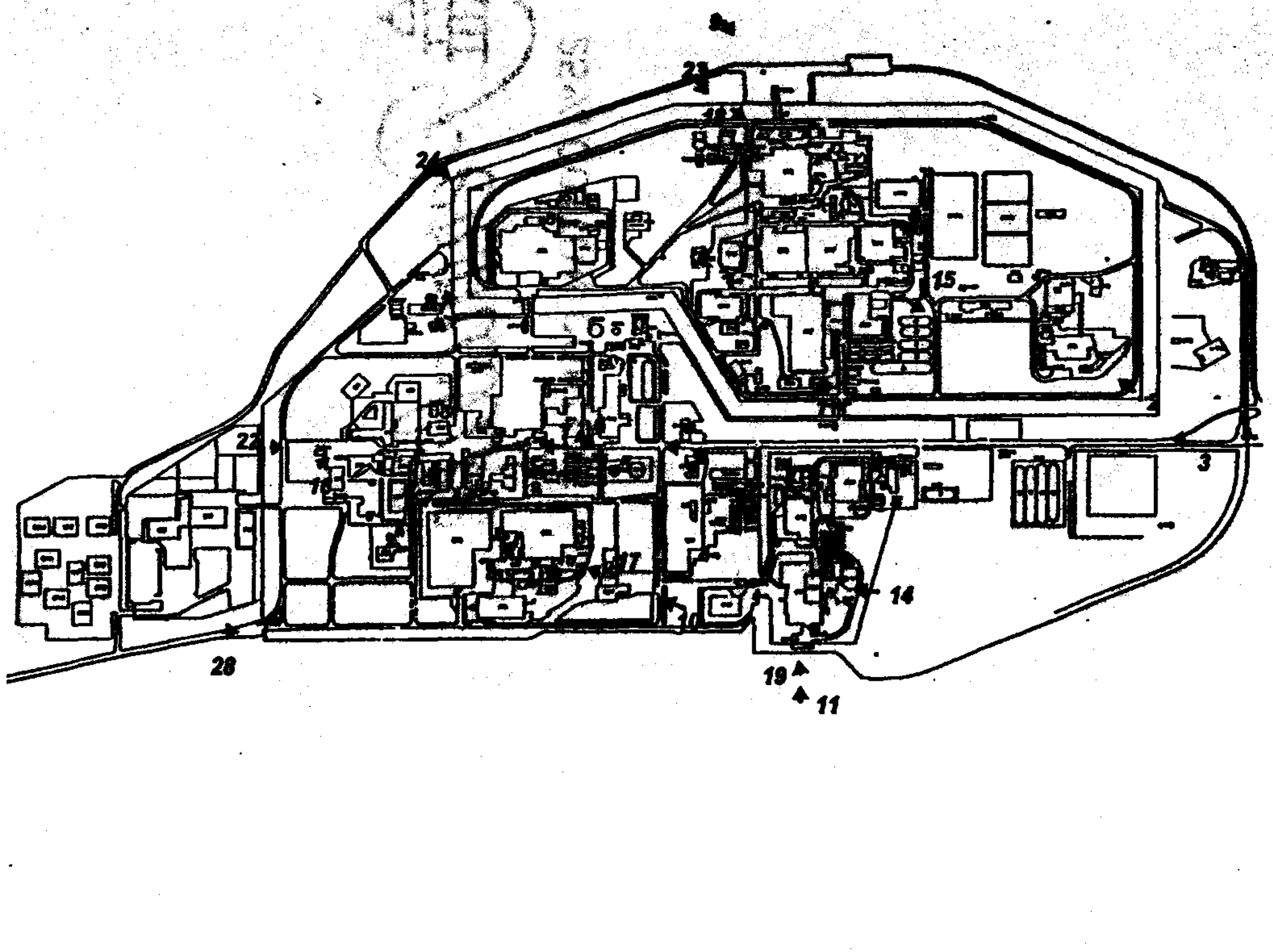

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HISTORIC AMERICAN ENGINEERING RECORD

ROCKY FLATS PLANT HAER No. CO-83
(Rocky Flats Environmental Technology Site)

Location: Bounded by Highways 93, 128, and 72 and Indiana Street, Golden, Jefferson County, Colorado.

Date of Construction: 1951-1953 (original plant).

Fabricator: Austin Company, Cleveland, Ohio.

Present Owner: United States Department of Energy (USDOE).

Present Use: Environmental Restoration.

Significance: The Rocky Flats Plant (Plant), established in 1951, was a top-secret weapons production plant. The Plant manufactured triggers for use in nuclear weapons and purified plutonium recovered from retired weapons (called site returns). Activities at the Plant included production, stockpile maintenance, and retirement and dismantlement. Particular emphasis was placed on production. Rocky Flats produced most of the plutonium triggers used in nuclear weapons from 1953 to 1964, and all of the triggers produced from 1964 until 1989, when production was suspended. The Plant also manufactured components for other portions of the weapons since it had the facilities, equipment, and expertise required for handling the materials involved.

In addition to production processes, the Plant specialized in research concerning the properties of many materials that were not widely used in other industries, including plutonium, uranium, beryllium, and tritium. Conventional methods for machining plutonium, uranium, beryllium, and other metals were continually examined, modified, and updated in support of weapons production. Cutting edge technologies developed at the Plant resulted in a number of patents, doctoral degrees, and numerous scientific discoveries. Early on, there were very few locations in the United States that had the capabilities to work with plutonium. Employees working at the Plant were leaders in the field.

The Plant is associated with the United States strategy of nuclear military deterrence during the Cold War, a strategy considered of major importance in preventing Soviet nuclear attack. The establishment of the Rocky Flats Plant was the result of the post-war fear of the Soviet Union; this fear drove the federal government to build a vastly expanded nuclear weapons production system.

The nuclear arms race resulted in the development of an immense research, production, and testing network that came to be known as the "Nuclear Weapons Complex." From the Manhattan Project to 1995, the United States spent over 300 billion dollars on nuclear weapons research, production, and testing (in 1995 dollars; USDOE 1995). During a half century of operations, the complex manufactured tens of thousands of warheads and detonated more than one thousand nuclear warheads.

At its peak, the "Nuclear Weapons Complex" consisted of thirteen major facilities, which included laboratories, production plants, testing facilities, and associated infrastructure. All of the thirteen sites had interrelated functions. The U.S. Department of Energy (USDOE) complex contains four types of facilities: a) nuclear sites (fabrication and assembly); b) non-nuclear sites (manufacture of non-nuclear components); c) laboratories and test sites (research and test support); and d) weapons assembly and disassembly.

<u>Historians:</u> D. Jayne Aaron, Environmental Designer, engineering-environmental Management, Inc. (e^2M), 1998. Judy A. Berryman, Ph.D., Archaeologist (e^2M), 1998.

<u>Project Information:</u>

In 1995, an inventory and evaluation of facilities at the Rocky Flats Plant for their potential eligibility for listing in the National Register of Historic Places was conducted. The primary goal of this investigation was to determine the significance of the Cold War era facilities at Rocky Flats Plant in order to assess potential effects of the long-term goals and objectives of the USDOE. These goals and objectives included waste cleanup and demolition. Recommendations regarding National Register of Historic Places eligibility were developed to allow the USDOE to submit a formal determination of significance to the Colorado State Historic Preservation Officer for review and concurrence and to provide for management of historic properties at the Rocky Flats Plant.

From this determination and negotiations with the Colorado State Historic Preservation Officer, the Advisory Council, and the National Park Service, a Historic American Engineering Record (HAER) project began in 1997 to document the Rocky Flats Plant's resources prior to their demolition. Also in 1997, the Rocky Flats Plant was officially listed on the National Register of Historic Places. The archives for this HAER project are located in the Library of Congress in Washington, D.C.

Information for this HAER project was gathered from declassified written materials and personnel interviews. All aspects of this project (this report, individual building reports, photographs, and drawings) have been reviewed by the Rocky Flats security organization and released as not containing any classified information.

Documentation for this HAER project includes a Plant-overview component (this written report followed by drawings and photographs), as well as reports and photographs of individual buildings considered contributing resources of the Rocky Flats Plant historic district.

This Plant-overview report is organized into the following topics, which can be found on the indicated page numbers:

A set of seventeen drawings and a series of current and historic photographs illustrate the Plant-overview report. The drawings delineate the geographic location of the Rocky Flats Plant; the Nuclear Weapons Complex; nuclear weapons production flow diagrams; the Cold War time line; the Rocky Flats Plant historic district; various production flow diagrams and building relationships; and health and safety, laboratory, and security aspects of the Plant. The photographs depict the original construction, growth of the Plant, the relationship of the buildings, and the setting. The individual building reports and photographs follow the Plant photographs.

For specific information regarding processes, construction, and history of each structure considered contributing resources of the Rocky Flats Plant historic district see the following documents.

HAER No.	*STUCTURE TYPE*	*STRUCTURE # (Similar structures included in report)*
CO-83-A	Critical Mass Laboratory	886
CO-83-B	Analytical Health Physics Laboratory	123
CO-83-C	Plutonium Laboratory	779
CO-83-D	Guardhouse	888 (446, 461, 557, 773, 864, 992)
CO-83-E	Storage Vault	996 (997, 998, 999)
CO-83-F	Bus Stop Shelter	114
CO-83-G	Guard Facility	120 (100, 113, 133, 900, 920)
CO-83-H	Guard Post	762 (372, 792, 764)

HAER No.	*STUCTURE TYPE*	*STRUCTURE # (Similar structures included in report)*
CO-83-I	Access Control Building	792A (372A, 762A)
CO-83-J	Guard Tower	901 (375, 550, 761)
CO-83-K	Plutonium Recovery Facility	371
CO-83-L	Non-Nuclear Production Facility	444
CO-83-M	Plutonium Manufacturing Facility	707
CO-83-N	Plutonium Recovery and Fabrication Facility	771
CO-83-O	Plutonium Processing Facility	776/777
CO-83-P	Design Laboratory	701
CO-83-Q	Manufacturing and General Support	881
CO-83-R	Uranium Rolling and Forming Operations	883
CO-83-S	Emergency Medical Services Facility	122
CO-83-T	Stainless Steel and Non-Nuclear Components Manufacturing	460
CO-83-U	Final Assembly and Shipping Facility	991
CO-83-V	Offices, Print Shop, and Photography Lab	111
CO-83-W	General Cafeteria	112
CO-83-X	Plant Security and Armory	121
CO-83-Y	Vehicle Maintenance Garage and Fire Station	331
CO-83-Z	Transportation Modification Center	440
CO-83-AA	Metal Research and Development Laboratory	865
CO-83-AB	Laundry Building	778
CO-83-AC	Water Treatment Plant	124
CO-83-AD	Standards Laboratory	125
CO-83-AE	Source Calibration Laboratory	126
CO-83-AF	Water Tower	215A
CO-83-AG	Filter Test Laboratory and Warehouse	442
CO-83-AH	Chemical Analytical Laboratory	559
CO-83-AI	Waste Treatment Facility	774

Abstract

The Rocky Flats Plant is one of thirteen major USDOE facilities that constitutes the Nuclear Weapons Complex which designed, manufactured, tested, and maintained weapons for the United States arsenal. A tense political atmosphere both at home and

abroad during the Cold War years drove United States weapons research and development. By the 1970s, both the United States and the Soviet Union maintained thousands of nuclear weapons aimed at each other, based on submarines, bombers, and intercontinental ballistic missiles. Both the North Atlantic Treaty Organization and Warsaw Pact countries in Europe had small nuclear warheads called "theater weapons" available to be used as part of the what was referred to as the Mutually Assured Destruction policy.

The doctrine of Mutually Assured Destruction was developed by then U.S. Secretary of Defense Robert McNamara, who argued that there would be effective stability between the United States and Soviet Union when each had a secure second strike capability in response to a surprise attack. He defined this condition as the ability to deter "by maintaining at all times a clear and unmistakable ability to inflict an unacceptable degree of damage upon any aggressor, or combination of aggressors - even after absorbing a surprise first strike." For the United States, this was defined as the ability to destroy 20 to 33 percent of the Soviet population, and 50 to 75 percent of Soviet industrial capacity (Colliers Encyclopedia CD-ROM, 1996).

The Rocky Flats Plant was a top-secret weapons production plant. The Plant manufactured triggers for use in nuclear weapons and purified plutonium recovered from retired weapons (called site returns). Activities at the Plant included production, stockpile maintenance, and retirement and dismantlement. Particular emphasis was placed on production. The Plant produced most of the plutonium triggers used in nuclear weapons from 1953 to 1964, and all of the triggers produced from 1964 until 1989, when production was suspended. The Plant also manufactured components for other portions of the weapons since it had the facilities, equipment, and expertise required for handling the materials involved.

The Austin Company began construction at the Plant in 1951. A temporary guard shack on the property was constructed in 1951 along Highway 93. Building 91 (later changed to 991) was the first permanent building, followed by a temporary administration building. Building 71 (771), 44 (444), and 81 (881) followed. In 1952, Buildings 11 (111), 12 (112), 21 (121), 22 (122), 23 (123), and 42 (442) were constructed. At the end of the year Buildings 111, 112, 122, 331, 334, 344, 551, 661, and 771 were occupied. The total cost by 1952 for construction was $2,500.000. By September 1953, the Austin Company's construction was finished, for a total cost of approximately $43 million. At completion, the Plant was composed of four widely separated areas, each one performing a different type of work. Plant A (444) fabricated parts from depleted uranium. Plant B (881) recovered enriched uranium and fabricated parts from it. Plant C (771) contained the plutonium operations, and Plant D (991) was the assembly and shipping point. Each of the four production buildings had guardhouses and a number of support buildings.

Operations at the Plant revolved around plutonium, depleted uranium, enriched uranium, beryllium, and stainless steel operations and can be divided into four general time periods: 1953-55, 1956-63, 1964-89, and 1989-92. The original two trigger designs at the Plant were modeled on the designs of the bombs that were dropped on Japan and made use of enriched uranium, depleted uranium, some plutonium, and beryllium. Triggers were fabricated and assembled in the 1950s in the original four plants - A, B, C, and D. Plant C (771) housed all of the plutonium processes; casting, machining, inspection, assembly, and recovery. The original plutonium recovery process was adapted from Los Alamos National Laboratory processes. The process was put into operation in 1953, with the first shipment of plutonium nitrate solution from the Hanford Plant. Later, the Rocky Flats Plant also received plutonium nitrate feed from the Oak Ridge Reservation. By 1959, all shipments of plutonium nitrate were discontinued. After that time, internally generated plutonium residues from Plant operations were the primary feed for the recovery/metal production.

Enriched uranium was one of the materials used to create the first-stage fission reaction in nuclear weapons. The trigger design of the early 1950s required large amounts of enriched uranium. Both fabrication and recovery of enriched uranium took place at Rocky Flats. Enriched uranium recovery operations were initiated shortly after fabrications operations began. Processes used at the Plant were based on those developed at the Los Alamos and Oak Ridge laboratories. The process was refined at the Oak Ridge Y-12 Plant preceding the construction of Rocky Flats. Enriched uranium was cast, shaped and formed, machined, inspected, and assembled into component parts for the triggers at Plant B (881).

Depleted uranium was used as a non-fissile component in the trigger design. Depleted uranium was cast in the foundry (Plant A, Building 444) into near-net shapes (close to the final product form), machined into finished parts, and inspected. Depleted uranium was shipped to the Plant from the Feed Materials Production Center in Fernald, Ohio. Some beryllium was also processed in Building 444, but as part of research and development for production engineering and weapons development, rather than as part of the regular manufacturing process.

Trigger components manufactured in Plants A, B, and C, as well as those manufactured at Oak Ridge, were sent to Plant D for assembly and storage. They were then shipped to the Pantex Plant in Texas for final assembly into the atomic weapon.

During the 1956-63 period of operations, the trigger was redesigned replacing the enriched uranium core with a plutonium core. This design change required a great deal more machining than the previous deslgns, resulting in the construction of a number of new buildings and a change in the uses of existing buildings. An estimated $21 million was spent on expansion. During this expansion, the Plant nearly doubled in size. New buildings included 701, 776/777, 883, 999, 114, and 778. Additions and modifications were added to Buildings 444, 881, and 771. The design change also meant that beryllium would be used to a greater extent than in the past. In 1958, beryllium operations became a standard part of the Plant operations.

Production scale operations of beryllium began in 1958, with a new trigger design. Beryllium was used as a neutron reflector. Production operations initially involved only the machining; off-site vendors conducted final inspection and assembly processes. By the mid-1960s Rocky Flats beryllium operations included the casting and shaping of beryllium parts. By 1975, foundry casting of beryllium on the Plant site ceased, with beryllium supplied in the form of blanks from off-site vendors. Machining of beryllium parts continued in Building 444 until production shut down in the late 1980s. Other than the recycling of parts from site returns (retired weapons), beryllium recovery operations were not conducted on the Plant site.

The next large scale change to the Plant came in the 1960s, when the Atomic Energy Commission chose to make Rocky Flats the sole producer of triggers under the "single mission" concept. During this time period, the manufacturing facilities and production processes did not change much, although the assembly lines were shifted from building to building. The majority of the Plant expansion during this time was driven by new weapons programs, higher safety standards, and expansion of production.

Plutonium fabrication continued at an expanded level with production continuing in Building 776/777. By 1967, construction had begun on a new plutonium facility (Building 707) to augment operations at Building 776/777. Also by 1968, new technologies had been developed for plutonium recovery from solid and liquid waste. A major fire in Building 776/777 in 1969 necessitated the relocation of some of its foundry, fabrication, and final assembly operations into the new Building 707.

As part of the single mission policy, enriched uranium operations were transferred to Oak Ridge Y-12 Plant between 1964-66. Production of enriched uranium components ceased at Rocky Flats in 1967. Building 881 operations were shut down and the building was decontaminated.

In 1966, stainless steel operations were transferred from New Mexico to Building 881. Stainless steel processing was done in Buildings 881 and 444 until Building 460 was completed in 1984. Stainless steel was used primarily to make the reservoirs that held tritium gas within the bomb. Stainless steel casting, forging, or recovery operations were not conducted on a production scale at the Plant. Production operations included machining, assembling, inspection and testing, and support.

During a routine inventory shutdown, in December of 1988, the Federal Bureau of Investigations (FBI) raided the Plant for alleged environmental violations. The raid resulted in an immediate suspension of plutonium weapons production at the Plant. During 1989-92, the Plant focused its activities on resuming operations to bring the Plant up to current safety and operational standards and to get back into weapons production. Significant changes occurred at the site after the 1989 FBI investigation. By 1991, a series of world events reduced the Cold War threat and the need for a plutonium trigger manufacturing facility. The temporary suspension of nuclear weapons production, in place since 1989, was made permanent in 1992, the mission of the Plant shifted to environmental restoration, waste management, and clean up and conversion of the Plant for new uses.

From its groundbreaking, the Rocky Flats Plant offered steady work and good wages. Regardless of the mission or time period, the Rocky Flats Plant contractors offered jobs to people with skills ranging from janitorial and support staff to highly skilled scientific personnel. The opportunity to work with cutting edge technologies led to many patents and advanced degrees. Employees working at Rocky Flats were leaders in the field, knew the latest techniques, and what could and could not be done. In 1951, the Plant employed about 133 people; in 1953 the number had risen to 1,059 employees. From 1957 to the end of the first expansion of the Plant in 1963, over 3,000 people were employed at the Plant. When the Atomic Energy Commission changed the Plant mission in the 1960s, employee population rose to over 3,700 (1970s). Under Rockwell and President Reagan's administration in the 1980s, the Plant population grew again to over 6,000.

As a top-secret weapons production facility, the Plant was concerned with security precautions from its inception. Indicative of the importance of security, the first structure on site was a small guard shed built in mid-May 1951. In comparison, excavation for the first permanent building on site, Building 91 (991), did not begin until July 10, 1951.

In the early years, security was concerned with the Cold War, espionage, and the secrecy associated with building nuclear weapons. It was important to safeguard design secrets, and later, the numbers of weapons being produced. Classified information was available only on a need-to-know basis; employees received instruction only on their specific duties. All employees were required to have a Q clearance, a top-secret level for atomic workers requiring a 15-year background check. Employees were forbidden to talk about their work with anyone. There were many instances of immediate family members working at the Plant, with no knowledge of what the other's job duties were. Very few employees knew what the final product was that was shipped to Pantex. What the workers did know was that whatever they were doing was important to national security, believing that their work was keeping communism from the United State's shores.

Through the 1950s and 1960s, employees were treated respectfully by most of the public. The public knew little about the work at the Plant, other than it was for military purposes. Public opinion began to change in 1969/70 with the fire in Building 776/777 and a strike between Dow and its union. Activities associated with the strike, along with public dissent regarding the Vietnam War, began to alter the public's perception of and opinions regarding the Plant.

In the 1970s and 1980s, the Rocky Flats Plant received the most attention from anti-war and environmental protesters of all sites within the USDOE Nuclear Weapons Complex. Plutonium was believed to be one of the most hazardous substances in existence; other facilities did not have plutonium in the quantities that Rocky Flats had. Non-nuclear production could have continued indefinitely at Rocky Flats; however, the local government and public no longer supported the Plant after the late 1980s. The last program, stainless steel operations, was transferred to Kansas City in 1995. Presently, all buildings associated with weapons production or use of plutonium at Rocky Flats are to be closed down and removed.

Cold War and the Nuclear Weapons Complex

The Political Climate Leading to the Cold War (1928-1946)

Political instability in Europe during the 1930s and 1940s fueled a perceived need for a nuclear weapon or atomic bomb. Just as the secrets of the atom were being discovered, both Europe and Asia were experiencing political instability (revolutions and the rise of dictatorships), along with concurrent policies of expansion and repression.

From 1928 to 1936, the Soviet Union was in the midst of Stalin's Great Purges. In the Far East, Japan began expansionist activities with the invasion of Manchuria in 1931. One year later, in Europe, Leo Szilard conceived the idea of an atomic-powered bomb. In 1933, Hitler became the Dictator of Germany, and the concept of the atomic bomb was patented one year after that. The same year that Germany began occupation of the German Rhineland (1936), Leo Szilard transferred the atomic bomb patent to the British government, so that it could be protected under British secrecy laws. Expansionist activities in Asia continued with the Japanese invasion of China in 1938. The next year the German Army occupied Austria and the Sudetenland portion of Czechoslovakia.

In December 1938, German scientists demonstrated nuclear fission. As Germany invaded Poland in 1939 and World War II began, nuclear weapons went from being theoretically possible to being probable. Scientists were beginning to understand the different fissionable properties of uranium 235 and uranium 238, an understanding necessary for the development of an atomic weapon. In 1939, Albert Einstein sent a letter to President Theodore Roosevelt concerning atomic research activities and the potential for making a bomb. In response to that letter, the United States formed a committee to investigate potential military applications of nuclear fission. The committee studied the issue, but did not immediately pursue military applications of nuclear energy.

Plutonium, destined to become the primary fissionable material used in atom bombs, was discovered in 1941. Later that same year, the United States entered World War II after the Japanese bombing of Pearl Harbor. Shortly thereafter, the United States initiated the precursor to the Manhattan Project. This project was initiated in part because the United States and its European Allies feared Hitler's pursuit of atomic weapons might be successful, resulting in the fall of Europe to Hitler's Army, and threatening the stability of the United States.

Summary of Key Political Events Leading to Cold War 1930 to 1945

DATE	DESCRIPTION
Sep 1931	Japan invaded Manchuria.
Jan 1933	Hitler appointed Chancellor of Germany.
Mar 1933	Hitler became dictator of Germany.
Sep 1935	Nuremberg Laws began persecution of Jews in Germany.
Mar 1936	Occupation of German Rhineland.
1928-36	Stalin's Great Purges.
Jul 1937	Japan invaded China.
Nov 1937	Axis Alliance was created between Germany, Japan, and Italy.
Mar 1938	Germany occupied Austria.
Sep 1938	Germany occupied the Sudetenland portion of Czechoslovakia.
Sep 1939	World War II began with German invasion of Poland / Nuclear weapons development became probable.
Oct 1939	President Roosevelt appointed an Advisory Committee on Uranium

DATE	DESCRIPTION
	(Briggs Uranium Committee).
Dec 1941	Japan bombed Pearl Harbor / United States entered the war.
Sep 1942	Manhattan Project began development of an atomic bomb
May 1945	May 8th - VE Day / Germany surrendered to Allies.
Jul 1945	United States exploded the first atomic bomb (gun type).
Aug 1945	United States dropped nuclear bomb on Hiroshima on the Aug 6th and Nagasaki on Aug 9th. Japan surrendered on Aug 14th.

Development of the Atomic Bomb

The development of the atomic bomb was tied directly to World War II and the race between Germany and the United States to develop such a crucial weapon. Many of the physicists working on its development in the United States were émigrés who had fled Nazi Europe and were driven by the desire to create a bomb before the German scientists did. In 1939, uranium fission was discovered, and the United States government was apprised of its military importance through a letter written by physicists Albert Einstein and Leo Szilard (Stein, 1984:5). The following year, President Roosevelt established the National Defense Research Committee. This committee supervised a uranium committee, which was working on the development of a nuclear chain reaction using uranium - the first step toward the production of a bomb.

From 1940 to 1942, physicists at various American universities performed experiments with lattice piles of graphite and uranium oxide to see what the "optimum lattice" would be. They were also determining the appropriate amount, shape, and placement of uranium within graphite needed to produce the desired fission. In 1942, these physicists gathered at the University of Chicago Metallurgical Laboratory, under the direction of Dr. Arthur Holly Compton, to work toward producing a chain reaction.

The chief difficulty at the time was in procuring uranium oxide in sufficient quantities and of sufficient purity for the needs of the lattice. The raw material, hundreds of tons of black uranium oxide, was finally bought from the Canadian Radium and Uranium Company, but it was not pure enough for the experiment with fission (Smyth, 1945: 45-74); however, Compton knew that uranium could be purified by ether extraction. Remembering his old friend Edward Mallinckrodt's experiments with ether and his company's safety record when working with the volatile material, he asked Mallinckrodt, in April of 1942, to tackle the important and potentially dangerous job of purifying 60 tons of uranium oxide in a matter of months. Mallinckrodt agreed, where owners of other large companies had declined, and he successfully produced the requisite amount of the material necessary for the fission experiment to succeed (Compton, 1956: 94-95). Leaving the Mallinckrodt Company as brown dioxide, the material was then shipped to the Westinghouse Company, where it was turned into metal for placement in the lattice (Smyth, 1945: 88-94).

The first self-sustaining nuclear chain reaction occurred in a squash court under the West Stands of Stagg Field at the University of Chicago on December 2, 1942. Once it was proved that fission could occur, work to develop the atomic bomb continued under a program called the Manhattan Project.

Several facilities were constructed by the Manhattan Engineer District to pursue development of the atomic bomb, each with a specific purpose. The first gaseous diffusion plant and nuclear reactor at Oak Ridge, Tennessee, were built in 1942. Oak Ridge served as the field headquarters for the Manhattan Project work to separate uranium 235 and produce plutonium for the atom bomb. In 1943, a second more isolated plant was built at Hanford, Washington, with larger reactors to produce plutonium from uranium for use in the bomb (Hewlett, 1962:188-190; Mazuzan, 1984:9-10). The same year, an isolated laboratory was established at Los Alamos, New Mexico under the direction of J. Robert Oppenheimer (Smyth, 1945: 222). Here, the first atomic bomb was designed, constructed, and demonstrated -- in July 1945 -- exploding at White Sands, New Mexico. This successful test culminated in the bombing of Hiroshima and Nagasaki, and the end of World War II.

Nuclear Weapon Development - The Manhattan Project

The Manhattan Project, as it became known, was officially started with the creation of the Manhattan Engineering District, as part of the United States Army Corps of Engineers in June 1942. The Manhattan Project was the code name for the United States' top-secret research project, with the goal of creating the world's first weapon powered by nuclear fission. The Manhattan Project was unique in that it was a collaboration of university scientists, industrialists, and military engineers. It was supported by a number of facilities devoted to weapons design, atomic research, plutonium production, and enriched uranium production and testing facilities. The Manhattan Project, costing in excess of $25 billion (1995 dollars), was successfully completed in less than three years, an incredible feat considering that properties had to be selected and acquired, research and production facilities designed and constructed, and personnel screened and hired before work could begin.

Colonel Leslie R. Groves was appointed District head in September, with the task of ensuring the development of the atom bomb. Colonel Groves quickly appointed a scientific project leader, Robert J. Oppenheimer, to solve the theoretical problems with fission bombs, design the weapon configuration, and fabricate the weapon at what would become the Los Alamos Laboratory. Groves and Oppenheimer worked closely together throughout the length of the project. Groves was in charge of the project schedule and development, particularly material and land acquisition, and construction of the facilities required to support the scientific endeavor. Oppenheimer was in charge of the scientific discoveries necessary for weapons design.

Los Alamos Laboratory was selected as the site for weapons design in November 1942 and was staffed in March 1943. Research at Los Alamos focused on two designs. One was a gun-type assembly, where criticality (a spontaneous nuclear fission chain reaction caused when a sufficient quantity of fissile material is placed within a given area) would be achieved by forcing together subcritical masses of highly enriched uranium to induce a nuclear reaction. The other design, an implosion-type assembly, relied on the use of a plutonium core, surrounded by a spherical assembly which, when imploded, would initiate a nuclear reaction.

Simultaneously, scientists at Oak Ridge Laboratory (also known as the Clinton Laboratories) and the Hanford site were doing the theoretical research necessary to obtain highly enriched uranium and to develop the reactors to create plutonium. The Hanford Site in Washington state was concerned with plutonium production and separation. At Oak Ridge, reactors were designed and constructed to produce plutonium and process facilities were constructed to produce highly enriched uranium.

The level of secrecy maintained in the Manhattan Project proved to be a blessing in disguise. Although it dictated remote site locations, required subterfuge in obtaining labor and supplies, and served as a constant irritant to the academic scientists on the project, it had one overwhelming advantage: secrecy made it possible to make decisions with little regard for normal political considerations. Secrecy in the Manhattan Project was so pervasive that many people working for the organization did not know what they were working on until they heard about the bombing of Hiroshima on the radio. The need for haste clarified priorities and shaped decision-making. Unfinished research on three separate, unproven processes had to be used to freeze design plans for production facilities, even though it was recognized that later findings inevitably would dictate changes. The pilot-plant stage was eliminated entirely, violating all manufacturing practices and leading to intermittent shutdowns and endless troubleshooting during trial runs in the production facilities. The inherent problems of collapsing the stages between laboratory and full production created an emotionally charged atmosphere with alternating optimism and despair. For such a large organization to take laboratory research into design, construction, operation, and product delivery in two and one-half years (1943 to Hiroshima) was a major industrial achievement.

By May of 1942, the decision was made to not delay production any longer. The decision to proceed with production planning led directly to the involvement of the United States Army, specifically the Corps of Engineers. President Roosevelt had approved Army involvement on October 9, 1941. The need for security suggested placing the program within one of the armed forces, and construction expertise made the Corps of Engineers the logical choice. With this reorganization in place, the nature of the American atomic bomb effort changed from one dominated by research scientists, to one in which the scientists played a supporting role in the construction enterprise run by the United States Army Corps of Engineers.

By the time President Roosevelt authorized the Manhattan Project on December 28, 1942, work on the East Tennessee site, where the first production facilities were to be built, was already underway. The last quarter of 1942 saw the acquisition of a roughly 90 square mile parcel in the ridges just west of Knoxville (the Oak Ridge Military Reservation). By the end of 1943, three plants were well under construction at the Oak Ridge Reservation: the Y-12 area, housing the electromagnetic plant; the X-10 area, which housed the experimental plutonium pile and separation facilities; and K-25, site of the gaseous diffusion plant. This site, until the end of World War II, was known as the Clinton Engineer Works. Early population estimates for the town and production workers were 13,000 people. By 1943, population estimates for the town had risen to 45,000 people. Oak Ridge was the fifth largest town in Tennessee, and the Clinton Engineer Works was consuming one-seventh of all the power being generated in the nation.

By the end of the war, the United States Army had spent approximately $2.2 billion on production facilities and towns built in the states of Tennessee, New Mexico, and Washington, as well as university laboratories from Columbia to Berkeley. In December 1942, investigations began for a second production site. Approximately 225 square miles were needed for a full-scale plutonium production facility. On February 22, 1943, a temporary office was set up in Hanford, Washington to purchase 144,000 acres in and around the Hanford-Pasco-White Bluffs area.

In 1944, the Manhattan Project ran into difficulties when the gun assembly weapon concept was the only workable design. Because of the difficulties with uranium enrichment facilities, there were no viable production methods. Conversely, production of plutonium was proceeding, but a viable weapon design was lacking. Highly enriched uranium production problems were solved by mid-year. The production of highly enriched uranium increased to the point where output at Oak Ridge went from 40 grams per day in November 1944, to 204 grams per day in January 1945. It was predicted that by July 1, 1945 sufficient uranium (40 kilograms) would be available for bomb production.

In the spring and summer of 1945, several events happened. In April, President Roosevelt died of a brain hemorrhage and the new President, Harry Truman, was briefed on the Manhattan Project. He had been unaware of the project or of the plans to drop the atom bomb on Japan to end the war in the Pacific. In May 1945, Germany formally surrendered to the Allies. The war in the Pacific was also nearing its end. Although military sources suggested that all the major cities in Japan would be bombed into submission by the end of the year, U.S. military casualties were expected to exceed 500,000 (Groves, 1962). President Truman and his military advisors were convinced that if the atom bomb could be used against Japan, it would serve as a diplomatic tool in postwar negotiations with the Soviets. On July 16, 1945, the United States detonated the world's first atomic bomb, a fission weapon, code name "Gadget," at the Trinity Test in New Mexico (see HAER No. NM-1).

On August 6, 1945, President Truman directed that the Enola Gay, a specially modified B-29 bomber, drop an atomic bomb on Hiroshima, the first use of an atomic weapon in war. This fission bomb released the equivalent of 12,500 tons of TNT. Three days later, on August 9, 1945, a second atomic bomb (also fission), releasing the equivalent of 22,000 tons of TNT, was dropped on Nagasaki, leading to an offer of unconditional surrender from Japan on August 14, 1945, accepted by the United States on August 15. Formal unconditional surrender of Japan to the United States was signed on September 2 ,1945.

The Hiroshima and Nagasaki bombings resulted in a formerly inconceivable amount of destruction from a single explosion. In Hiroshima, approximately 140,000 deaths were attributed to the atomic bomb by the end of 1945. In a single event, the explosion destroyed 4.4 square miles (11.4 sq km) of a densely populated city, and more than 90% of all buildings were damaged, two thirds of them completely. Although the tonnage detonated in Nagasaki was nearly the double that of Hiroshima, the damage was considerably less. Casualty levels were approximately half of Hiroshima, and 36% of the buildings were damaged. This lower level of destruction is attributed to the long narrow shape of the city, and the protection to outlying areas afforded by hills (Colliers Encyclopedia CD-ROM, 1996).

Considerable debate continues over the use of nuclear weapons by the United States and the its ultimate effect on ending the war. Initially, the immediate surrender of Japan was attributed solely to the use of atomic weapons. From a historical perspective, standards of conduct held at the beginning of World War II were much different than those at the end of the war. Many events aided this change in perception, including Hitler's bombing of Rotterdam and later London; Germany's use of ovens to kill millions of Jews and other minorities; Japan's attack on Pearl Harbor and its brutal treatment of prisoners; the Bataan death march; and the bombing of Shanghai. Early in the European arena, the British initially refused to drop bombs on civilian targets; they dropped leaflets instead. Likewise, the United States initially focused on military targets, however, this soon gave way to more indiscriminate bombing of cities and civilian targets (Kagan, 1995). Five months prior to the dropping of the atomic bomb, an intense conventional fire bombing campaign had been engaged. Aerial raids using conventional bombs over Tokyo on March 9-10, 1945, resulted in an estimated 100,000 deaths, wounded a similar number, destroyed more than 250,000 buildings, and left hundreds of thousands homeless (Sweeney, 1997, and Kagan,1995).

Initially, the American people supported the use of nuclear weapons against Japan as an effective method of reducing anticipated American casualties in the final invasion of Japan. Projected casualty estimates ranged from a high of over one million American deaths (and a similar number of Japanese) to less than 40,000.

Aside from reducing the number of casualties, it has also been suggested that the United State's used nuclear weapons in an attempt to strengthen their hand in anticipated postwar negotiations with the Soviet Union, which had entered the war in the Pacific only days earlier. Other more recently suggested motivations included a desire to see tangible results from the investment in the weapons development program, and an experimental curiosity to see how the bombs would actually work. Regardless, it is likely the United States believed that due to the ferocity of the Japanese troops, their use of kamikaze suicide attacks, and their history of not surrendering, the use of nuclear weapons was required to shock them into unconditional surrender (Encyclopedia CD-ROM, 1996).

As shown in "Key Events Associated with Nuclear Weapons Development," although radiation was first discovered in 1896, it was not until the 1930s that a concentrated effort to develop an atomic weapon was initiated. From the discovery of uranium fission in December 1938 by German scientists, it took less than seven years to explode the first atomic bomb at White Sands, New Mexico in 1945.

Key Events Associated with early Nuclear Weapons Development

DATE	DESCRIPTION
1896	Discovery of radiation, first evidence of the fundamental structure of matter.
1905	Quantum Theory was developed.
1932	Leo Szilard conceived of the idea of a chain reaction of neutron collisions with atomic nuclei to release energy and the potential to use this reaction to create a

DATE	DESCRIPTION
	bomb.
1934	Leo Szilard filed patent for atomic bomb – patent described chain reaction and concept of critical mass.
1936	Patent was transferred to British Government for protection under secrecy laws.
Dec 1938	Direct evidence of fission was observed and correctly explained by Otto Hahn.
Jan 1939	Leo Szilard understood the theory in his atomic bomb patent had been realized and the creation of a bomb was possible.
Feb 1939	The different fissionable properties of uranium 235 and 238 were measured (providing crucial insight to development of the bomb).
July 1939	The Graphite-moderated-reactor concept advanced.
Oct 1939	President Roosevelt appointed committee to study military implications of atomic research.
Feb 1941	Plutonium was created.
Sep 1941	Britain began development of atomic bomb.
Dec 1941	United States began work on atomic bomb – predecessor to Manhattan Project
Apr 1942	Design began on world's first human-built nuclear reactor (Fermi).
June 1942	Manhattan Engineer District of United States Army Corps of Engineers is designated. Colonel Leslie Groves appointed District head.
Sep 1942	Colonel Groves took over the Manhattan Project.
Sep 1942	Colonel Groves purchased land for Oak Ridge Reservation.
Oct 1942	Colonel Groves appointed Dr. J. Robert Oppenheimer as head of what would become the Los Alamos Laboratory.
Dec 1942	First self-sustaining nuclear chain reaction occurred (CP-1) under the squash court at Stagg Field (University of Chicago) – reactor contained 36.6 metric tons of uranium oxide, 5.6 metric tons of uranium metal, and 350 metric tons of graphite.
Jan 1943	Hanford Engineer Works was acquired to build plutonium production reactors and separation plants.

DATE	DESCRIPTION
1943	◆ Construction of plutonium plant at Hanford site. ◆ Construction of Uranium Enrichment plants (gas diffusion, electromagnetic) Oak Ridge. ◆ Refinement of gun-assembly weapon design at Los Alamos (high priority). ◆ Preliminary implosion weapon design at Los Alamos (lower priority).
Fall 1943	Project Alberta begins – prepared for actual combat delivery of weapon.
1944	Work proceeded in weapons development, fissile material production, and weapons delivery.
June 1944	Contract for S-50 thermal diffusion producing plant for highly enriched uranium.
July 1944	Fission measurements were too high for a plutonium gun assembly weapon – shifted emphasis to implosion.
July 1944	Los Alamos shifted full priority to implosion research; required all resources.
Aug 1944	Air Force began modification of B-29 bombers for delivery of atomic weapons.
Sep 1944	◆ Total production of enriched uranium was only a few grams. ◆ Only workable bomb design (gun assembly) had no bomb material production method available. ◆ Plutonium production technique had high probability of success, but no weapon design.
Sep 26 1944	B-Pile plutonium reactor at Hanford goes on-line and spontaneously shuts down.
Late 1944 to Early 1945	◆ Highly enriched uranium output at Oak Ridge increased from 40 to 90 to 204 grams per day in November, December, and January, respectively. (July 1st was predicted as date for production of the 40 kilograms sufficient for bomb production.) ◆ Feasibility of implosion bomb design was demonstrated. ◆ Large-scale plutonium production began at Hanford B-Pile reactor.
Feb 1945	Gun design was completed and frozen.

DATE	DESCRIPTION
Feb 1945	F-reactor went on-line at Hanford – theoretical production up to 21 kilograms per month.
Mar 1945	◆ Thermal diffusion plant at Oak Ridge began highly enriched uranium production. ◆ Implosion bomb design approached frozen; evidence that the design worked.
May 8 1945	◆ VE Day / Germany surrendered to Allies. ◆ Little Boy was ready except for uranium 235 core / Estimate enough available by August 1st.
Jun 1945	Implosion core design confirmed.
Jul 1945	◆ Casting of uranium 235 projectile for Little Boy was complete. ◆ Gadget (test weapon) was assembled on July 6th. ◆ Little Boy shipped out on July 9th. ◆ Gadget was exploded on July 16th / Explosive yield was 20-22 kilotons of TNT.
Aug 1945	◆ August 6th - Little Boy (gun design) was dropped on Hiroshima. ◆ August 9th - Fat Man (implosion weapon) was dropped on Nagasaki.
Jul 1946	Atomic Energy Act was passed, creating the Atomic Energy Commission; replaced the Manhattan Project.
1949	Soviet Union exploded its first plutonium implosion bomb.
Jan 1950	Truman ordered development of hydrogen bomb.
1951	Construction of the Rocky Flats Plant begins.
Oct 1952	United States exploded its first hydrogen bomb (thermonuclear bomb).
Aug 1953	Soviet Union exploded its first prototype-hydrogen bomb.
Aug 1953	Completion of the initial 21 buildings at Rocky Flats (four production buildings along with guard houses and support buildings).
1953	Production of nuclear triggers at Rocky Flats.
Jan 1954	First nuclear submarine launched with range of 62,500 miles without refueling.
1954	First warhead for missile was built.
1955	Soviet Union exploded its first "successful" hydrogen bomb.

DATE	DESCRIPTION
1957	Britain exploded its first hydrogen bomb.
1960	France exploded its first atom bomb.
1963	United States and the Soviet Union signed the first limited test ban treaty prohibiting underwater, atmospheric, and outer space testing.
1964	Enriched uranium operations (manufacturing and recovery) transferred to Oak Ridge; manufacture of all triggers transferred to Rocky Flats.
1964	China exploded its first atom bomb.

The Cold War (1946-90)

Tensions between the Soviet Union and the United States in the immediate aftermath of World War II soon dashed any hopes for an international agreement controlling atomic energy. Political instability experienced during the 1930s-1940s continued into the early Cold War Era, fostering a perceived need for nuclear weapons and driving the major super powers towards developing various weapons research and development programs (often referred to as the nuclear arms race). In the United States and the Soviet Union, the nuclear arms race resulted in the development of a vast research, production, and testing network.

The Cold War was the term applied to the competition between the United States and the Soviet Union that developed after the end of World War II and continued until 1990. This period was marked by heightened tensions between communist and capitalist nations. Instability and increased tension across the globe was used to achieve ideological, political, and economic goals, and most importantly, resulted in the massive buildup of nuclear arsenals on both sides of the conflict.

There are many opinions regarding the causes of the Cold War. Some schools of thought attribute the conflict to the American desire for an open-door economic policy around the world. The Cold War was fueled by ideological differences, the capitalist United States wanted equal economic access in the Balkans and a rebuilt capitalist Europe, with an economically healthy Germany to serve as an economic hub. The United States also supported the concept of self-determination to establish independent nations, particularly in Poland. The Soviets had different plans for Europe. They were determined to dominate the Balkans, control Poland (a historic gateway for German invasions of the Soviet Union) and destroy Germany's capacity to start another war. Others cite the Cold War as a justified response by the United States to the threat of Soviet aggression and the communist/Leninist theory of inevitable conflict between communist and capitalist forces. Another school of thought attributes the Cold War to the policy of deterrence, with each side trying to out-threaten the other.

Between 1945 and 1947, Stalin, the Soviet leader, drew what was termed an "iron curtain" across eastern Europe, and sealed East Germany, which had been given to the Soviets as part of war reparations (Drawing 4). This "iron curtain" eliminated the pre-war exchange of information enjoyed by scientists and academics; limited diplomatic communication; restricted free trade; and eliminated travel between communist and noncommunist nations.

The competition between the superpowers quickly spread from central and eastern Europe to the Middle East and Asia. Later it spread to emerging nations in Africa and ultimately, to the Western Hemisphere. Between 1945 and the 1960s, the competition involved the governments of Turkey, Iran, Greece, Berlin, Vietnam, Korea, Japan, China, Guatemala, Cuba, Chile, Hungary, Poland, Egypt, Czechoslovakia, and Angola, with the United States and Soviets, each trying to expel the other's influences and maintain control.

After the end of World War II, a number of economic plans and alliances were developed to restore shattered economies, deal with heightened tensions, and respond to perceived adversarial moves. In 1947, the Truman Doctrine was pledged to protect free peoples from the threat of communism, no matter how repressive their governments. By 1948, the United States sponsored the Marshall Plan, an economic package designed to revitalize Western Europe. This was followed in 1949 by the North Atlantic Treaty Organization, an alliance of eleven nations who pledged to help protect each other's borders from communist expansion. The Soviets responded to the Marshall Plan with a program to tie together the economies of eastern Europe by forming the Council for Mutual Economic Assistance; by organizing a blockade of Berlin; and by forming a Sino-Soviet alliance with China.

The Soviets began their own nuclear weapons development program, culminating in the explosion of the first Soviet nuclear weapon in 1949. The arms race officially began with that 1949 detonation. One month after the Soviet nuclear detonation, President Truman ordered work to begin on the development of the fusion bomb, alternately referred to as a hydrogen bomb, H-bomb, or thermonuclear bomb.

As the postwar era entered the 1950s, the conflict spread to other parts of the world. The United States pledged economic and military support to Vietnam and proposed a peace treaty with Japan, which included United States operated military bases. To neutralize United States power in Japan, the Soviets responded by supporting plans by communist North Korea to invade South Korea. Communist China soon joined forces against the

United States and South Korea. Fighting eventually stabilized along the 38th parallel. Although a peace treaty was signed in 1953, the conflict between the communist North and capitalist South had not ended nearly 45 years later. In Europe, West Germany was formally admitted to the North Atlantic Treaty Organization in 1952 and rearmed.

The political tensions between the United States and the Soviet Union drove weapons research and development. Since 1948, when United States scientists discovered a way to produce low-yield nuclear warheads in large quantities, the continued threat of Soviet expansion became the reason to produce tactical nuclear weapons in large numbers. At that time, President Truman approved a major expansion of the atomic program with a corresponding development of smaller bombs and missile warheads for installation in Europe.

Between 1947 and 1952, the Atomic Energy Commission initiated the construction of facilities that increased United States weapons production capacity enormously. The new facilities included: three additions to Oak Ridge gaseous complex; gaseous diffusion plants in Paducah, Kentucky and Portsmouth, Ohio; five additional reactors for producing plutonium at Hanford, Washington; and five heavy water reactors for producing tritium from lithium, and for producing plutonium, at the new Savannah River, South Carolina, site. In addition, the Commission constructed auxiliary facilities to enlarge and strengthen the production chain from uranium ore to weapons. These included a feed materials production center at Fernald, Ohio, and component plants at Rocky Flats, Colorado and Amarillo, Texas. By summer 1952, 150,000 workers were engaged in atomic weapons-related construction activities.

In 1953, the Atomic Energy Commission developed a high-yield, lightweight atomic weapon. This "thermonuclear breakthrough" combined with a report that the Soviets were developing long-range ballistic missiles, led U.S. President Dwight Eisenhower to assign the highest priority to development of an intercontinental ballistic missile that could carry these lightweight weapons. The United States detonated the first fusion, or hydrogen bomb, in 1954. This was exponentially more powerful than the atomic bomb, with the equivalent force of 10 megatons (10,000,000 tons) of TNT (the Hiroshima atomic bomb had an equivalent force of 12,500 tons of TNT).

U. S. President Dwight Eisenhower, through the Central Intelligence Agency, helped to overthrow governments sympathetic, or feared to be sympathetic to communism. This included Iran in 1953 and Guatemala in 1954. The United States faced down Soviet aggression in the Middle East in 1956, and in West Berlin between 1958 and 1961. American forces were sent into Lebanon in 1958 to maintain its pro-United States stance. Economic aid and military advisors were sent to build an independent South Vietnam.

Meanwhile, the Soviet leader, Nikita Khrushchev, established new relations with India and other key neutral nations, formed an alliance with Cuba after Fidel Castro's communist revolution, and created the Warsaw Pact in 1955 to counter West German admittance to the North Atlantic Treaty Organization and subsequent rearmament. In 1956, the Soviets used the Warsaw Pact to suppress unrest by military force in communist bloc nations of Poland and Hungary protecting them from capitalist influences.

A United States "bomber-gap" panic occurred between 1954 and 1957, based on an erroneous United States Intelligence report that the Soviets had more long-range bombers than the United States. A "missile gap" panic followed during the years 1957 to 1961, caused by the Soviet launches in 1957 of Sputnik, the world's first satellite, and the world's first intercontinental ballistic missile. This perceived technological imbalance between the United States and the Soviet Union, coupled with the Gaither Report (1957, which discredited United States military preparedness and urged a 50 percent increase in military spending) led to a high infusion of money into United States weapons research and development. Between 1958 and 1960, the American nuclear stockpile of weapons tripled, with nearly all the triggers for these weapons manufactured at Rocky Flats (Drawing 3).

According to declassified nuclear stockpile information released by the U.S. Department of Defense and Department of Energy, by 1960, the United States nuclear stockpile consisted of more than 18,000 weapons, with a total capacity exceeding 20,000 megatons of force. Over 7,000 new weapons were added to the United States stockpile that year. A year later, in 1961, the number of nuclear weapons had increased to more 22,000 weapons, but total force had decreased to less than 11,000 megatons, primarily due to replacement of existing higher tonnage warheads with smaller, more accurate weapons.

This buildup was in response to the United States' fear of Soviet nuclear attack, and to that end, in 1961, President Kennedy urged American citizens to build bomb shelters to protect them from a nuclear war. In 1961, the Berlin Wall was constructed, separating Soviet-controlled East Berlin from West Berlin.

As American nuclear superiority grew, the Soviets countered by placing nuclear weapons in Cuba in 1962, resulting in the Cuban Missile Crisis, and pushing the world to the brink of nuclear war. One result of this crisis was the Limited Test Ban Treaty, banning nuclear tests in the air and under water after 1963. Otherwise, the military buildup continued.

Throughout the 1960s, the superpowers vied for control of de-colonized Africa, the Middle East, Asia and Latin America. In 1965, the United States landed troops in the

Dominican Republic to prevent the emergence of another hostile communist leader, and the Soviet Union repressed a reform movement in Czechoslovakia in 1968. To prevent the further spread of nuclear weapons technology, the Soviet Union, United States, United Kingdom, and 133 other non-nuclear weapons nations signed the Nuclear Non-Proliferation Treaty.

During the 1970s, both the United States and Soviet Union maintained thousands of nuclear weapons, based on submarines, bombers, and intercontinental ballistic missiles. Both the North Atlantic Treat Organization and Warsaw Pact countries in Europe had small nuclear warheads called "theater weapons," available to be used as part of the Mutually Assured Destruction policy advanced by then U.S. Secretary of Defense Robert McNamara. The goal of this policy was to deter the Soviet Union and its allies from a first strike nuclear attack by ensuring a massive retaliation by the United States. McNamara estimated that although 100 million Americans might die in a first strike, the United States would retaliate by an immediate, massive launch that could destroy an estimated 20 to 33% of the Soviet population and 50 to 75% of Soviet industrial capacity. Sophisticated weapons of this period included missiles armed with multiple warheads.

Summary of Major Cold War Events

DATE	DESCRIPTION
Mar 1946	Winston Churchill proclaimed Iron Curtain had come down across Europe.
Jul 1946	Atomic Energy Act was passed, creating the Atomic Energy Commission, which replaced the Manhattan Project.
1949	Soviet Union exploded its first plutonium implosion bomb.
Dec 1949	New process increased production of enriched uranium.
Jan 1950	Truman ordered development of the hydrogen bomb.
1950	♦ McCarthyism began a four-year reign of accusations and suspicion. ♦ Fallout shelters were built as part of a major civil defense program. ♦ June: Outbreak of Korean Conflict. ♦ Development of Redstone Rocket (ground-to-ground ballistic missile for nuclear war) began.
Oct 1952	Great Britain exploded its first atom bomb.
Oct 1952	United States exploded its first hydrogen bomb (thermonuclear bomb).

DATE	DESCRIPTION
1953	The Rosenbergs were executed for acting as spies for the Soviet nuclear weapons program.
Aug 1953	Soviet Union exploded its first prototype hydrogen bomb.
Dec 1953	Oppenheimer lost his security clearance due to hydrogen bomb opposition and 1930s communist connections.
1953-54	United States, through the Central Intelligence Agency, helped to overthrow governments sympathetic to communism (Iran in 1953, Guatemala in 1954).
1955	Creation of the Warsaw Pact by the Soviet Union to counter anti-Communist movements.
1955	Soviet Union successfully exploded a true hydrogen bomb.
1957-1961	Perceived "bomber-gap" by the United States led to high infusion of money into weapons research and development.
1958	United States' policy of massive retaliation was pursued.
1961	President Kennedy advised United States civilians to build bomb shelters.
1961	Berlin Wall was erected.
1962	Cuban Missile Crisis occurred.
1963	United States and the Soviet Union signed the first limited test ban treaty prohibiting underwater, atmospheric, and outer space nuclear weapons tests of atomic weapons.
1970s	Continuation by both the United States and the Soviet Union of the "arms race".

The huge military buildup by the Soviets and United States began to take a toll on the economies of both countries. In 1972-73, United States President Richard Nixon signed the Strategic Arms Limitation Treaty (SALT I) with the Soviet Union leader Leonid Brezhnev to limit costly strategic arms and strengthen United States-Soviet economic ties in a period of détente. This period did not last long, as the United States and Soviets competed with each other for influence in outbreaks in the Middle East, Chile, and Angola. Internal United States politics altered the SALT I Treaty during Senate confirmation to the point that it was rejected by Soviet leader Brezhnev in 1975. President Jimmy Carter's SALT II Treaty was undercut by world events, including the

Iranian Revolution in 1979, which ended a pro-United States regime, the communist-aided Nicaraguan Revolution, and the Soviet invasion of Afghanistan.

Relations between the United States and Soviets, already on a downward slide, worsened in the 1980s, with United States President Reagan's military increases and policy of confrontation with the Soviets. The combination of increased military spending and economic problems resulted in the United States going from the world's leading creditor nation to the world's leading debtor nation in 1985.

Meanwhile, the Soviet nuclear arsenal had reached a peak of 45,000 weapons (Drawing 4). That same year, Mikhail Gorbachev gained power and, faced with a collapsing economy, began making major concessions to the United States in the areas of conventional forces, nuclear weapons, and removal of internal immigration controls. The Soviets pulled their troops out of Afghanistan and the Berlin wall fell that year. In 1990, the Cold War officially ended with the Conference on Security and Cooperation held in Europe (Drawing 4). By 1991, the breakup of the Soviet Union with the subsequent dissolution of the Warsaw Pact had occurred. In that year, U.S. President George Bush ordered all bombers and tankers to be taken off alert, and the U.S. Department of Defense began to reconsider its needs in terms of the size and nature of its military force. Department of Defense began cutting its military force and cutting back on the production of new weapons.

Societal Impacts of the Cold War

Public support was high at the end of World War II, after all, the atomic bomb was considered to have ended the war, saving possibly hundreds of thousands of American lives. Due in part to this initial support, Americans lived with the idea that nuclear weapons might be used again. Citizens constructed bomb shelters and stocked them with canned goods, bottled water, and first aid kits. The public, urged on by President John F. Kennedy, believed these shelters would protect them from the effects of nuclear fallout. Bomb shelters were constructed in schools and other public buildings, and school students in the 1950s and 1960s routinely practiced nuclear bomb drills. Public announcements warned citizens from looking directly at a nuclear blast.

Society's perception of the United States nuclear weapons program changed dramatically throughout the years. Eventually, certain elements of American society rebelled against the use of nuclear weapons and against the status quo in general, leading to protests, rallies, marches, meetings, and publications against nuclear war, nuclear weapons production, and the Vietnam War to name a few. Other groups rallied to save the environment and for expanded civil rights. While, much of the disagreement over these issues was peaceful, violent confrontations did take place. In 1972, the first color photograph that showed the whole earth from outerspace was published. This image showed a fragile looking earth of land and sea, without the demarcation of nations. This image was partly responsible for creating the environmental movement, because it created a totally different vision of what the earth's future might be (Brauner, 1996).

In the late 70s and 80s, with the passage of key legislation (i.e. the Endangered Species Act, and the Resource Conservation and Recovery Act), protection of the environment became more mainstream. The public began to be more conscious of safety issues related to the United States nuclear weapons program, and also environmental protection. As the threat of Soviet attack diminished in the mid to late 1980s, the principles of environmental stewardship, and public safety increased in importance, eroding public support of the United States nuclear weapons program.

Repercussions of the Cold War are still being argued; however, there is no doubt that the electronics and information industries are a direct legacy of fifty years of competition with the Soviets. The number of discoveries and technological innovations made as a direct result of the Cold War and the pace of those discoveries is staggering. Advances made in communications, electronics, computers, and other fields have changed the way the world runs.

Cold War Advances in Nuclear Weapons Design

The first nuclear weapons were designed and assembled by scientists in a laboratory at Los Alamos in 1945. After World War II ended, there was pressure for immediate simplification of the assembly process so that specially trained military personnel could assemble atomic bombs. It took several years for this to be achieved. The Mark 4 implosion system, tested in the Spring of 1948, ended the laboratory-style layout of weapons, and opened the way for mass production and use of assembly-line techniques.

In 1951, the basic nuclear weapon design was established in the United States and the subsequent effort was concentrated on making weapons lighter and smaller. In 1952, the United States detonated a thermonuclear, or hydrogen bomb, that had an equivalent force of 10 megatons of TNT. The Soviets detonated their first hydrogen bomb in 1953, followed by Great Britain in 1957 and France in 1960.

Initially, nuclear weapons were bombs, which had to be dropped from aircraft. To deploy a nuclear device, it first had to be taken from a storage facility and loaded onto a specially modified plane to meet the mission of the moment. Under the policy of massive retaliation in response to Soviet attack, the missiles had to be ready for immediate use. Thus, during the 1950s, the United States began to integrate carriers and warheads, resulting in a specific tailoring of the warhead to the weight and shape characteristics of the missile carrier. A primary consequence of the carrier and warhead integration was that the missile system (missile with nuclear warhead) could be launched from any number of locations within the United States, from aircraft, watercraft, and from within the borders of other nations allied with the United States.

This continuing trend toward military rather than peacetime uses of nuclear energy came about in part because of the change in the political climate from 1945 to 1950. At that time, the stance of the United States toward the Soviet Union, its World War II ally, hardened into enmity, which translated into what became known as the Cold War. Through a series of events in the Soviet Union in 1948-49 -- such as the detonation of its first atomic bomb, its blockade of Berlin, and its growing influence in neighboring China culminating in the Communist takeover -- the United States came to believe that the Soviets were planning both to claim the world for Communism and to eradicate the United States through a surprise nuclear attack (Clarfield and Wiecek, 1984:144).

President Truman responded to the Soviet threat with a policy declaration, NSC-68 (National Security Council) in 1950 that committed the United States to the arms race against the Soviet Union. Additionally, Truman approved the production of fusion weapons (i.e., the hydrogen bomb) and other nuclear weapons as the method for deterring Soviet attack. The Atomic Energy Commission was directed to produce "more and bigger bombs," to build reactors to produce plutonium, and to develop uranium and other raw materials (Clarfield and Wiecek, 1984:122-34). The outbreak of the Korean War in the same year convinced the United States that the Soviet Union was poised to attack Europe after decoying forces away from Europe to Korea. The United States detonated a hydrogen bomb in 1952 and the Soviet Union did the same in 1953.

The establishment of the Rocky Flats Plant was the result of this post-war fear of the Soviet Union, a fear that drove the federal government to build a vastly expanded nuclear weapons production system (Drawing 2). It was one of a number of plants built by the Atomic Energy Commission between 1948 and 1953 to design, manufacture, test, and maintain nuclear weapons for the United States military. It has been estimated that by 1952-53, the height of expansion, the Atomic Energy Commission was employing 150,000 construction workers -- equal to 5 percent of the United States construction work force -- to fabricate its necessary military nuclear facilities (Hewlett, 1962:587; Dietz, 1962:158).

Between 1950 and 1953, gaseous diffusion plants to extract uranium 235 were built in Paducah, Kentucky and Portsmouth, Ohio. Five heavy water reactors to produce plutonium and tritium were built at Savannah River, Aiken, South Carolina, and those already in existence at Oak Ridge and Hanford were expanded between 1950 and 1953.

A number of research laboratories were constructed as well to supplement the research being done at Los Alamos Laboratory, including the Mound Laboratory at Miamisburg, Ohio and the Lawrence Livermore National Laboratory in Livermore, California. The Los Alamos Laboratory, taken over from the Manhattan Engineering District in 1946 by the Atomic Energy Commission, continued to conduct nuclear weapons research, development, testing, production, and storage (Dietz, 1962: 158-9).

The Nevada Test Site, established in 1951, was the location of a number of field tests of bombs developed at Los Alamos. Originally (1946) the tests took place at Bikini Atoll, and later Eniwetok Atoll in the Marshall Islands. With the announcement in 1949 that the Soviet Union had exploded its own atom bomb and the outbreak of the Korean War in 1950, the United States wanted both to expand its number of tests and find a test site closer than the Pacific Ocean. There were sixteen tests in 1951 alone, twelve at the Nevada Test Site. After the Limited Test Ban Treaty of 1963 that forbade such atmospheric testing, the Nevada Test Site continued with underground test explosions, worked on miniaturizing warheads which made possible development of Multiple Independently Targeted Re-entry Vehicles, used on intercontinental ballistic missiles (Dietz, 1962: 163; Kaplan, 1982: 68, 96).

Six additional facilities were built to support the nuclear weapons program, including the Sandia Laboratory, The Idaho National Engineering Laboratory, the Mound Plant, the Kansas City Plant, the Pantex Plant, and the Pinellas Plant. In 1946, the Sandia Laboratory, under United States Army control during World War II, became the field headquarters of the United States Defense Atomic Support Agencies. It developed and tested atomic weapons. First under the control of the University of California, it was taken over in 1949 by the Sandia Corporation. The Idaho National Engineering Laboratory at Idaho Falls, Idaho, was established in 1949 as the National Reactor Testing Station, using materials from Oak Ridge, Paducah, Portsmouth, Savannah River, and Hanford in its experimental reactors. The Mound Plant was established at Miamisburg, Ohio in 1948 operated as the Monsanto Company to manufacture explosive detonators for the weapons program. The Kansas City plant was built in 1949 in Kansas City, Missouri, to produce electrical and mechanical components for the weapons program. The Bendix Company operated it. The Pantex Plant, in Amarillo, Texas, had been built in 1942 to build conventional bombs and shells, and was reactivated in 1951 as the site where all the weapons components produced at the other plants were finally assembled into weapons. The Pinellas Plant in Largo, Florida was established in 1957 to manufacture neutron generators (Buffer, 1995; *Citizen's Guide to Rocky Flats,* 1992).

The Atomic Energy Commission Nuclear Weapons Program

The US nuclear weapons program has been the responsibility of various government-authorized entities. These have included the U.S Army Manhattan Engineering District (Manhattan District), the Atomic Energy Commission, the Energy Research and Development Administration, and lastly the U.S. Department of Energy (USDOE).

The world's first atomic weapons were developed under the Manhattan Project, administered by the Manhattan District. World War II ended with the use of atomic bombs in Japan in August 1945. At that time, the United States was the only country to possess the knowledge of atomic weapons. After the war, the Manhattan Project was terminated, and was eventually replaced with a peace-time program. By July 1946, Congress passed the Atomic Energy Act and appointed the Atomic Energy Commission to oversee the national atomic energy program. Projects associated with the Manhattan Project were not transferred to Atomic Energy Commission control until 1947.

In the first few post-war years, the United States held a monopoly on atomic energy and the production of nuclear weapons. The Atomic Energy Commission was a civilian group that had the directive to develop both military and peacetime uses for the newly discovered nuclear energy. It was to be the owner of existing nuclear facilities and any fissionable material that would be produced in the future. Through the influence of Enrico Fermi, who had worked on the original bomb, the priority concentrated on the development of uranium and other raw materials for weapons production and the manufacture of bombs, rather than for peacetime applications (Clarfield and Wiecek, 1984:113, 121).

During the years from 1946 to 1950, Atomic Energy Commission's first mandate was to rehabilitate the wartime plants, find additional sources of uranium and plutonium, continue to carry out scientific research, and create and stockpile atomic weapons. Each year, the President determined the number of bombs to be made as part of the Atomic Energy Commission military program, and the Atomic Energy Commission carried out the President's mandate (Stein, 1984:8). At this stage, all nuclear bombs were made at Los Alamos from materials shipped from Hanford or Oak Ridge (*Citizen's Guide to Rocky Flats,* 1992).

The Atomic Energy Commission had retained the contractors from the Manhattan Project, and consequently was able to continue working with highly trained civilians after the war (Mazuzan, 1984). Mallinckrodt Chemical Works in St. Louis, Missouri was one of the private firms that continued to provide the Atomic Energy Commission with purified uranium for the Hanford reactor. The Atomic Energy Commission built a new plant on the company's property in 1947. Another feed materials production plant was built at Fernald, Ohio in 1952 to augment the supply from Mallinckrodt.

This expanded endeavor to strengthen the weapons production program from the initial procurement of uranium ore through the production of weapons created a system of research, engineering, testing, manufacturing and stockpiling of weapons that was monumental in scope. As a result of testing, the hydrogen bomb was successfully detonated in 1952 at Eniwetok Atoll, under the code name Operation Ivy, and refined in a series of subsequent tests between 1954 and 1958. After that tlme, laboratory and test goals were to manufacture smaller warheads that could be used on a variety of delivery vehicles, such as bombers, intercontinental ballistic missiles, and rockets.

The Atomic Energy Commission was tasked with the responsibility of directing the national atomic energy program. The paramount objective of the Commission in the 1940s and 50s was defense and security. Issues that required immediate attention included national security, retention of nuclear facilities and experienced personnel, control of the nuclear material stockpile, dissemination or sharing of information with other nations, establishing the direction of the United States nuclear program, and setting new goals. All requests for fissionable material were funneled through the Atomic Energy Commission and the review committee that was established to aid and advise the commission. Due to the extreme difficulty in creating fissionable materials, and the extremely small national stockpile of nuclear material, potential uses were limited. As military applications had higher immediate priority than non-military applications, the entire nuclear stockpile was dedicated to weapons development.

In the rush to successfully develop and deploy a nuclear weapon, security concerns were not given full scrutiny, and generally considered less important than ability. As the hectic pace of the United States nuclear program slowed, there was time to consider a new, stricter set of security measures, including full background checks for personnel with access to classified information. The Atomic Energy Commission developed a new set of security clearances for nonmilitary personnel. These procedures and security clearances are still in place today. All information associated with the United States nuclear program was classified as secret, and all individuals with access to classified information had to undergo a security clearance review. This led to development of the "Q clearance" which was required for all non-military personnel with access to nuclear information.

United States Nuclear Energy Program

The Atomic Energy Act was amended in 1954, allowing the Federal government and private industry to promote nuclear power in partnership. Until that time, all nuclear information was in the hands of the government. This new partnership resulted in a shift in emphasis from strictly military applications to allow industrial peacetime uses of nuclear energy.

An energy crisis occurred in the early to mid-1970s, leaving the United States with an inadequate energy supply. The Energy Reorganization Act of 1974 resulted in the creation of the Energy Research and Development Administration and the Nuclear Regulatory Commission. The Nuclear Regulatory Commission was given the licensing and regulatory functions previously under the Atomic Energy Commission. The Energy Research and Development Administration was tasked with focusing federal programs to promote speedy development of energy technologies. The Energy Research and Development Administration also retained oversight of military applications of nuclear energy. The U.S. Department of Energy (USDOE) replaced the Energy Research and Development Administration in 1977. The USDOE, the 12th cabinet level department, is responsible for the United States Nuclear Weapons Complex.

The USDOE Nuclear Weapons Complex

The nuclear arms race resulted in the development of a vast research, production, and testing network that came to be known as the "Nuclear Weapons Complex." From the Manhattan Project to 1995, the United States spent over 300 billion dollars on nuclear weapons research, production, and testing (in 1995 dollars)(USDOE 1995). During a half century of operations, the complex manufactured tens of thousands warheads and detonated more than one thousand nuclear warheads.

At its peak, the complex consisted of thirteen major facilities, including laboratories, production plants, and testing facilities; and numerous smaller facilities including warehouses, mines, and storage areas (Drawing 2). All of the thirteen sites had interrelated functions. The USDOE complex contains four types of facilities: 1) nuclear sites (fabrication and assembly); 2) non-nuclear sites (manufacture of non-nuclear components); 3) laboratories and test sites (research and test support); and 4) weapons assembly and disassembly.

The thirteen major facilities of the United States Nuclear Weapons Complex included:

- Hanford Site (Hanford, Washington; 1949) - fuel fabrication, irradiation;
- Lawrence Livermore National Laboratory (Livermore, California; 1949) - weapons research and design;
- Idaho National Engineering Laboratory (Idaho Falls, Idaho; 1949) - chemical separation,
- Rocky Flats Plant (Golden, Colorado; 1951) - warhead triggers;
- Los Alamos National Laboratory (Los Alamos, New Mexico; 1949) - weapons research and design;

- Sandia National Laboratory (Albuquerque, New Mexico; 1946) - weapons engineering;
- Pantex Plant (Amarillo, Texas; 1942) - high explosives fabrication, final warhead assembly;
- Kansas City Plant (Kansas City, Missouri; 1949), - non-nuclear component fabrication;
- Mound Plant (Miamisburg ,Ohio; 1948) - fabrication of actuators, ignitors, and detonators;
- Oak Ridge Reservation (Oak Ridge, Tennessee; 1943) - deuteride and uranium enrichment, component fabrication (highly enriched uranium, depleted uranium, and lithium);
- Savannah River Site (Aiken, South Carolina; 1952) - fuel and target fabrication, irradiation, chemical separation, and tritium production;
- Pinellas Plant (Largo, Florida; 1957) - production of neutron generators; and
- Nevada Test Site (Las Vegas, Nevada; 1951)- weapons and weapons component testing

The rest of this record describes historical events, construction history, and actions at the Rocky Flats facility.

<u>Rocky Flats Plant</u>

Site Location

In 1950, the Dow Chemical Company in Midland, Michigan was chosen by the Atomic Energy Commission to establish the Rocky Flats Plant (named later for its location) as an alternative fabrication facility for Los Alamos that would manufacture triggers for atomic bombs. F.H. Langell of Dow was placed in charge Dow in turn chose the Austin Company of Cleveland as the architectural/engineering firm in charge of construction (Buffer, 1995). The site of the Rocky Flats Plant, with the code name "Project Apple," was chosen after a lengthy study by the Austin Company, in consultation with the Santa Fe Operations Office of the Atomic Energy Commission at Los Alamos, and the Dow Chemical Company. The criteria for siting such a plant were that it be located west of the Mississippi River, north of Texas, south of the northern border of Colorado, and east of Utah. Additionally, it required a dry, moderate climate, a supporting population of at least 25,000 people, attractive surroundings for future workers, and accessibility from Los Alamos, Chicago, and St. Louis (The Austin Company, 1951).

Twenty-one areas in the United States were suggested initially as potential sites; only Denver satisfied all of Atomic Energy Commission's criteria. An added bonus was that a number of the workers at the Los Alamos facility came from Denver, and it was assumed that these people would be willing to relocate to the new facility. Within the Denver area itself, seven locations were screened for the additional requirement that the site be isolated from residential areas and close to the airport. Two sites, an area north of the Rocky Mountain Arsenal and Rocky Flats were chosen. The site near the Arsenal was discarded because of its light soil that would blow in a windstorm and because the Atomic Energy Commission facility would have to share an electric power transmission line with the Arsenal (History Associates Incorporated, 1987:67-69).

Denver enthusiastically received news of the site in 1951, when a Good Friday issue of *The Denver Post*, under the headline "There's Good News Today" announced the Atomic Energy Commission's plans to build the Rocky Flats Plant. Citizens, as well as the Boulder mayor, the Denver Chamber of Commerce president, the University of Colorado president, and both Colorado senators, expressed great pride in the choice of the Denver-Boulder area as the site for an atomic plant. Their patriotic sentiments were expressed well in the *Rocky Mountain News*: "We are proud that the area has been chosen for another important contribution to the nation's strength and future security" (Kennedy, 1994:11-12).

The original layout of the site was based on what the United States thought the enemy's (Soviet Union) weapons capabilities were at the time. Buildings had to withstand a specific magnitude of a blast at a certain distance from the site. To achieve this, the first production buildings were sunk in the ground so that the shock of a blast would then pass over the tops of the buildings. By 1957, when additional production buildings were constructed, it was recognized that with the enemy's weapons being more accurate and larger, the Soviet Union had the capability to destroy an underground building. After that point, the remaining buildings were built above ground (Calkins, 1998 interview).

As the properties of nuclear materials became known, and public concern for the environment grew, attitudes began to change. In 1975, a state task force appointed to study the Rocky Flats Plant concluded that the siting of the plant, with its vast amount of plutonium and potential for nuclear accidents, so close to the metropolitan area of Denver, had been a mistake. A 1988 report submitted to Congress indicated that the Plant's facilities were aging, waste storage and cleanup were major problems, and the public was opposed to the siting. The following year, the Federal Bureau of Investigation investigated the Plant for alleged environmental infractions, charges that were later proved unfounded by a Grand Jury (Kennedy, 1994:29-30; Thompson, 1 October 1993).

Mission of the Plant

The Rocky Flats Plant was established in 1951 to manufacture triggers for use in nuclear weapons and to purify plutonium recovered from retired weapons (called site returns).

During the 1950s, the desire was to get Los Alamos out of weapons production and back into design. However, national policy at the time required that in the event of a labor strike or a nuclear attack by the Soviet Union, all critical elements of weapons production could be duplicated at another facility (Calkins, 1998 interview). Los Alamos National Laboratory retained capabilities for trigger production, although the majority of the triggers in the nuclear weapons stockpile were manufactured at Rocky Flats. Information on specific weapons containing Rocky Flats-built nuclear triggers remains classified. However, it is known that triggers built at Rocky Flats were used in multiple weapon types, including individual bombs, warhead (air to air, antiballistic, advanced cruise, air launched, air to surface, surface to surface, and antisubmarine warfare) missiles, artillery shells, and atomic demolition munitions.

For a nuclear explosion to occur, the fissile material in a trigger created a first stage fission reaction, which would ignite a second stage reaction causing fusion of hydrogen into helium. The second stage reaction created the nuclear explosion. The trigger contained the majority of the fissile material in a nuclear weapon. Parts were formed from plutonium, uranium, beryllium, stainless steel, and other materials. From 1953 until 1992, the mission of the Rocky Flats Plant was the production of nuclear weapons components. The Rocky Flats Plant also disassembled retired weapons to recover plutonium for reuse in weapons production.

Selection of a weapons program involved a number of critical phases that determined what facility or plant would receive additional or new contracts. In general, there are seven basic phases that are considered part of the weapons program development. These phases are:

- Phase 1 Conception
  The military would decide it needed a new weapon to perform a specific task. The military would meet with the design labs at Los Alamos or Lawrence Livermore; parameters of the weapons would be determined.
- Phase 2 Feasibility studies
  Department of Defense and USDOE would prepare an agreement for development and procurement responsibilities.
- Phase 3 Development Engineering (prototype study)
  A development program, based upon required military characteristics, would be undertaken. A complete design would be developed.
- Phase 4 First Production
  The military would select one agency (Department of Defense, USDOE, sometimes both) to further design and in many cases, a test unit would be built. The majority of the test units were built at Rocky Flats.

- Phase 5 Preliminary production
  Selection of a lab and production facility and an assembly facility to produce the weapon. Under the dual capability policy, there were two design labs, two production facilities for each component, and two assembly points (Pantex and Burlington, Iowa).
- Phase 6 Quantity Production and Stockpile Maintenance
  Full-scale production would commence and weapons would be stockpiled.
- Phase 7 Retirement and disassembly .

The number of programs going on at an individual plant varied to a maximum of ten to twelve. Eight programs were considered the norm (Calkins, 1998 interview). There were many variables from one weapons design to another, with changes ranging from minor modifications to major advances in sophistication, tolerances, and production techniques.

An itemized list of Rocky Flats Plant weapons programs or products is not available for public release because the information is classified. However, Rocky Flats Plants products are an integral component of virtually every nuclear weapon that has been or is in the national stockpile, as well as virtually every nuclear test.

Depending on specific time periods, mission statements for Rocky Flats have included:

- Developing and producing nuclear weapons components from plutonium alloys, beryllium, stainless steel, and depleted uranium;
- Recovery and reprocessing of plutonium from site returns (retired weapons) and from by-product residues from manufacturing and recovery operations;
- Fulfilling USDOE/Department of Defense new deployment and testing requirements-supporting design agency development and testing for Nevada Test Site triggers, non-nuclear hardware, and other production agency development;
- Conducting in-house technology and process development;
- Providing weapons trainers (training modules) and mockups;
- Disassembly and evaluating triggers from stockpiles;
- Providing reliability evaluation programs; and
- Fabrication and modification tractors and trailers for safe secure transport.

While specific periods of expansion at the Rocky Flats Plant (1956-57 and 1964-65) cannot be attributed to specific political and military actions, the Plant's overall growth can be seen in the context of the huge expansion of military weapons during the 1950s and 1960s, when the United States and the Soviet Union became locked in an arms race. After the fall of the Berlin Wall (1989), the Soviet pullout of Afghanistan (1989), the end of the Cold War (1990), and the dissolution of the Warsaw Pact (1991), the threat of the nuclear was significantly reduced, signaling the eventual cessation of nuclear weapon production in the United States.

Significance

Under the National Register of Historic Places, the Rocky Flats Plant was considered exceptionally significant under Criterion A at the national level under the Cold War military theme: Development of Atomic Weapons for Military Purposes. Its period of significance dates from its inception in 1951 to its mission change in 1992 after the Cold War ended. The Plant's particular significance came from being the sole producer of triggers of nuclear weapons from 1964 to 1989 (Drawing 6).

Of the buildings at the site, sixty-four structures are considered directly related to the mission of the Plant and are considered contributing properties to the Rocky Flats Plant historic district. Buildings central to the Plant's mission include (listed by Building No. and HAER Report No.):

- Production Work:
  Buildings 371 (CO-83-K), 444 (CO-83-L), 460 (CO-83-T), 701(CO-83-P), 707 (CO-83-M), 771 (CO-83-N), 776/777 (CO-83-O), 881 (CO-83-Q), 883 (CO-83-R), 991 (CO-83-U), 996 (C0-83-E), 997, 998, 999;
- Research and Development:
  Buildings 125 (CO-83-AD), 126 (CO-83-AE), 559 (CO-83-AH), 779 (CO-83-C), 865 (CO-83-AA);
- Worker Safety/Health:
  Buildings 112 (CO-83-W), 114 (CO-83-F), 122 (CO-83-S), 123 (CO-83-B), 331 (CO-83-Y), 442 (CO-83-AG), 778 (CO-83-AB), 886 (CO-83-A);
- Security:
  Buildings 100, 111 (CO-83-V), 113, 120 (CO-83-G), 121 (CO-83-X), 133, 372, 372A, 375, 440 (CO-83-Z), 446, 461, 550, 557, 761, 762 (CO-83-H) 762A, 764, 773, 792, 792A (CO-83-I), 864, 888 (CO-83-D), 900, 901 (CO-83-J), 920, 992;
- Administration:
  Building 441;
- Infrastructure:
  Buildings 124 (CO-83-AC), 215A (CO-83-AF), 443, 551, 995;
- Maintenance:
  Buildings 333, 334; and
- Production Waste Treatment:
  Buildings 374, 774 (CO-83-AI).

It should be noted that an individual HAER may contain information applicable to other buildings. The following HAER documents contain information on additional buildings as indicated.

- Report CO-83-E includes information applicable to Buildings 997, 998, and 999.
- Report CO-83-J includes information applicable to Buildings 375, 550, and 761.
- Report CO-83-D includes information applicable to Buildings 446, 461, 557, 773, 864, and 992.
- Report CO-83-G includes information applicable to Buildings 100, 113, 133, 900, and 920.
- Report CO-83-H includes information applicable to Buildings 372, 792, and 764.
- Report CO-83-I includes information applicable to Buildings 372A and 362A.
- If no HAER number is listed, information is included in this report (Buildings 441, 443, 551, 995, 333, 334, and 374).

The original configuration of administration, maintenance, infrastructure, and waste treatment buildings (built between 1951 and 1953) controlled the original layout of the site. These buildings were necessary for both Plant function and in meeting the needs of employees in a remote and secured work place. The remaining administration, office, maintenance, infrastructure, waste treatment, and storage buildings were built to accommodate an increase in production and site population. These structures supported redundant rather than new, functions at the site. Temporary structures (mostly trailers) and various storage structures and tents provided additional space for a variety of technical and administrative tasks. Structures built after 1989, when production ceased, were considered non-contributing elements to the overall historical significance of the Plant.

<u>Plant Site Overview</u>

The Rocky Flats Plant Site

The total Plant site consisted of 6,500 acres in northern Jefferson County, Colorado, approximately sixteen miles northwest of Denver and twelve miles from Boulder and Golden. It was situated on a plateau at the eastern edge of the Front Range of the Rocky Mountains (Drawing 1). The site was divided into three geographic areas, each fenced and protected by security forces (Drawing 6). The industrial area, 384 acres, was located in the center of the Plant site. There were 436 structures that included approximately 150 permanent buildings and ninety temporary trailers, plus temporary structures, sheds, tanks, or parts of larger buildings. Most of the structures were industrial in design, constructed out of concrete, concrete block, or corrugated metal. The Protected Area was located within the northern portion of the industrial area and contained a complex of plutonium production facilities. This area was heavily fenced and guarded. The buffer zone, the remaining 6,116 acres, surrounded the industrial area and protected the site from potential encroachment. The Rocky Flats Plant historic district consists of sixty-four contributing resources dating from 1951 to 1989 within the industrial area of the nuclear weapons production plant.

The Plant was a self-contained concentration of industrial buildings surrounded by ranch land, preserved open space, mining areas, and a low-density residential area. The original site was 1,900 acres and an additional 4,600 acres was purchased in 1972. The initial 4-square mile acreage required for the Rocky Flats Plant was acquired through condemnation when negotiations over price with the three owners of the land, G.W. Lindsay, Katherine B. Church, and Frank A. Rodgers, failed to be concluded satisfactorily ("Chronology of Rocky Flats Plant", n.d.). In 1995, 234 acres in the northwest corner of the site were transferred to the USDOE, Golden Field Office to be used as a scientific wind turbine testing facility for development of alternative energies.

Plant Organization

Operations of the Rocky Flats Plant fell under the administration of the United States Atomic Energy Commission from 1951 until the Atomic Energy Commission was dissolved in January 1975. Responsibility for the Plant was then transferred to the Energy Research and Development Administration, which was succeeded in 1977 by the United States Department of Energy (USDOE).

The primary role of the USDOE was to provide the contractor with the parameters for operating the Plant, and to manage the operations contract. Dow Chemical Company, USA (Dow) was the prime operating contractor of the facility from 1951 until 1975. Rockwell International (Rockwell) succeeded Dow from 1975 through 1989. EG&G, a company founded by Edgenton, Germeshausen and Grier, assumed operations on January 1, 1990 after the Plant had ceased producing nuclear weapons components, although non-nuclear production continued for another two years. By 1993, the Plant had transitioned to a cleanup mission. Kaiser-Hill Company assumed operations in 1995.

In 1951, the Atomic Energy Commission assigned Rocky Flats two main weapons-production missions: the fabrication of nuclear weapons components (specifically plutonium triggers) and disassembly of obsolete weapons returned to the site (site returns) to recover and reuse valuable plutonium and uranium. Recycling operations were conducted to recover plutonium and enriched uranium from processing scraps and residues. Support programs associated with previous operations included waste handling and storage, special nuclear materials (fissile materials) accounting, laboratories, tool manufacturing, research and development, and providing utilities and maintenance facilities. Research programs pursued the development of improved methods and techniques in both fabrication and chemical processing.

Activities at the Rocky Flats Plant concerned Phases 4 through 7 of the seven phases of the weapons program development (first production; preliminary production; quantity production and stockpile maintenance; and retirement and dismantlement), with particular emphasis on preliminary and quantity production. Rocky Flats produced most of the plutonium triggers used in nuclear weapons from 1953 to 1964, and all the triggers produced from 1964 until 1989, when production was suspended.

The Plant also manufactured plutonium components for other portions of the weapons since it had the facilities, equipment, and expertise required for handling the materials involved. A component is a single part of a weapon, which is joined with other components to form a subassembly or an assembly, or larger pieces of a weapon. Assemblies are then joined with other components and assemblies to form a complete weapon. Assemblies and components are specifically created for each individual weapons program. A code number such as W76 or W88 identifies each program.

The Original Plant Construction 1951 - 1953

Austin Company began construction at the Plant in 1951 (Drawing 7). Mr. D.W. Persons, the Atomic Energy Commission Project Engineer assigned to the Plant, established a temporary office in a garage in Denver, to which personnel from the Austin Company moved as well. A temporary guard shack on the Rocky Flats property was constructed in 1951 along Highway 93. Building 91 (later changed to 991) was the first permanent building, followed by a temporary administration building. Buildings 71 (771), 44 (444) and 81 (881) followed. In 1952, Buildings 11 (111), 12 (112), 21 (121), 22 (122), 23 (123) and 42 (442) were constructed. At the end of the year, Buildings 111, 112, 122, 331, 334, 344, 551, 661, and 771 were occupied. The total cost by 1952 for construction was $2,500,000. In 1952, a railroad spur from the Denver and Rio Grande railroad, an access road, power lines, and telephone lines were built. At this time, Gilbert Hoover replaced D.W. Persons as Field Manager of Rocky Flats (Buffer, 1995).

By September 1953, the Austin Company's construction was finished, for a total cost of approximately $43 million, and there were twenty-one permanent buildings on site. By November, there were 1,200 employees (Buffer, 1995). The Plant was composed of four widely separated areas, each one performing a different type of work. Plant A (444) fabricated parts from depleted uranium. Plant B (881) recovered enriched uranium and fabricated parts from it. Plant C (771) contained the plutonium operations, and Plant D (991) was the assembly and shipping point (ChemRisk, 1992:51). Those facilities handling the more highly radioactive plutonium were located on the north side of Central

Avenue at a distance from the other buildings on site. Facilities handling the less radioactive enriched uranium and depleted uranium were located on the south side of Central Avenue and some distance from it. The support buildings were located along Central Avenue closest to Plant A, the least radioactive facility of the production buildings. The main administration area was referred to as the "Lump Sum Area" (Calkins, 1998 interview).

The completed Plant in 1953 contained the four production buildings with their guard houses, and a number of support buildings including an administration building (111), cafeteria (112), plant safety building (121), medical emergency building (122), paper shredder shed (122S), health physics building (123), hazardous storage shed (123S), garage and fire station (331), paint and blast shop (333), maintenance shop (334), production support building (441), laundry (442), heating plant (443), warehouse (551), sealed gas storage building (552), metal fabrication building (553), storage building (554), waste storage and emergency breathing air building (714), temporary electric shop (772), waste treatment plant (774), sewage treatment plant (887), and a waste water treatment plant (995). Originally each production plant had its own cafeteria; Building 112 was used by those employed in the administrative section of the Plant.

Access to the Plant was from the west on a very rough dirt road that eventually became Highway 93. Initially employees drove the route in their own cars, but soon discovered that the wear and tear on their vehicles was so bad that it was better to ride the bus. The Denver-Boulder Bus Company established an additional route between Golden and Boulder to serve plant commuters, and termed it the "atomic plant route" (Kennedy 1994:13). There were other hardships concerning employee vehicles on site. Personal cars were only allowed to travel as far as perimeter parking. Employees were then bused to the Plant buildings. The high winds blew gravel from the parking lots onto the cars, removing the paint. The wind was often so strong, particularly when there were few buildings on site, that employees held hands, forming a chain to avoid being blown over. To everyone's relief, a new oiled State Highway 93 was built in 1954 (Buffer, 1995).

History of Operations

1953-55

The original two trigger designs at the Plant were modeled on the designs of the bombs that were dropped on Hiroshima (Little Boy) and Nagasaki (Fat Man), both involving solid cores of fissile materials. The Little Boy design contained two solid masses of uranium at opposite ends of a tube that were forced together by an explosion to achieve criticality. The Fat Man design had a small plutonium core surrounded by a large amount of enriched uranium and then by explosives. The detonated explosives caused the uranium and plutonium to implode to a reduced volume to cause criticality. These initial-generation trigger designs made use of enriched uranium, depleted uranium, some plutonium, and beryllium. Triggers were fabricated and assembled in the 1950s in the original four Rocky Flats Plants A, B, C, and D (ChemRisk, 1992; R. Dickey, personal communication, 1995).

Enriched uranium, the largest component of the trigger, was supplied by the Oak Ridge Reservation's Y-12 plant as hockey puck-shaped buttons. The buttons were cast, shaped and formed, machined, inspected, and assembled into component parts for the triggers at Plant B (Building 881). Enriched uranium recovery and purification of the waste from manufacturing these triggers also took place in Plant B. Floors in the chemical salvage area and a machining room were covered with stainless steel sheets to make cleaning easier. A large part of the early work at the Plant took place in this building, since the triggers required large amounts of enriched uranium (ChemRisk, 1992) (Drawing 12).

Depleted uranium was cast and machined in Plant A, Building 444. The material was shipped to the Plant originally shaped as the crown of a derby hat from Paducah, Kentucky, and later as ingots from the Feed Materials Production Center in Fernald, Ohio. The material was cast in the foundry close to the final product form (in near-net shapes), machined into finished parts, and then inspected. These components were then sent to the Pantex Plant in Texas for assembly (ChemRisk, 1992:76). Some beryllium was also processed in Building 444, but as part of research and development for production engineering and weapons development, rather than as part of the regular manufacturing process. Like the depleted uranium, it was cast in the foundry into shapes that were then machined (ChemRisk, 1992:74) (Drawing 13).

Plant C, Building 771, housed all of the plutonium processes, including casting buttons of plutonium metal feed stock; fabrication of component parts from the buttons; coating, inspection, testing, and storage of weapons components; and the recovery of plutonium from wastes created during this manufacturing process. The plutonium was created in reactors at Hanford, Washington; Savannah River, South Carolina; and sometimes from Oak Ridge, Tennessee. It came to the Plant in the form of either plutonium nitrate liquid or as buttons (Drawing 9).

Trigger components manufactured in Plants A, B, and C, as well as those manufactured at Oak Ridge, were sent to Plant D for assembly and storage. They were then shipped off site to the Pantex Plant in Amarillo, Texas for final assembly into the atomic weapon.

1956-63

In 1956, a design change was made in the triggers, from a solid, mostly uranium core to a hollow, mostly plutonium core that was lighter than the previous units and could be made smaller (Drawing 7). The plutonium buttons were machined into hollow hemispheres that were then joined. This hollow design required a great deal more machining than the previous designs. The same materials were used but in a different ratio and form (ChemRisk, 1992:45-7). Such a change required the construction of a number of new buildings and a change in the uses of existing buildings. An estimated $21 million was spent on the expansion, called Part IV, and the Plant nearly doubled in size by 1962 (Buffer, 1995). A number of new buildings, including Buildings 701, 776/777, 883, 999, 114, and 778 were built, as well as additions to Buildings 444, 881, and 771. Further additions to the Plant were continuous, with several buildings added each year.

With a greater use of plutonium required, the facilities in Building 771 were no longer adequate, and a plutonium fabrication and foundry building, 776/777, was constructed in 1956-57. Plutonium recovery operations remained in Building 771. Casting took place in the 776 side of Building 776/777. Rolling, forming, and machining operations were located in the eastern side of 776. Inspection, assembly, and storage were conducted in the 777 section of Building 776/777 (EG&G, 1994:1-4; 9-2) (Drawing 9). Because the trigger was more complex, it was assembled in Building 776/777 rather than at Building 991. After assembly, the units were packed and shipped off site or sent to Building 991 for staging prior to shipping (EG&G, 1994:9-7).

The new trigger design called for the rolling and forming of both enriched and depleted uranium as well (Drawings 12 and 13). Building 883 was constructed in 1957 adjacent to Building 881 for rolling and forming uranium. Depleted uranium was cast into ingots in Building 444, sent to Side A of Building 883 for rolling and forming, and then returned to Building 444 for machining and inspection. After 1958, depleted uranium was fabricated on site from billets imported from Ohio. Enriched uranium was cast in Building 881 (enlarged for manufacturing in 1956), sent to Side B of Building 883 for rolling and forming, and returned to Building 881 for machining and inspection. A reinforced concrete tunnel was constructed in 1957 to transport enriched uranium between the two buildings (EG&G, 1992, 1994).

Building 447 was added to the southwest corner of Building 444 in 1956 to house equipment to anneal depleted uranium parts, assemble parts from Building 444, and to process wastes. Building 445 was added to the east side of 444 in 1957 to house the carbon shop that supplied graphite molds and crucibles to the foundries in Buildings 444 and 776. Building 448 was added to the north side of Building 447 in 1962 to house production control offices. Building 451 housed the exhaust filter plenum and exhaust fans for Buildings 447 and 448 (EG&G, 1992, 1994).

The design change for triggers also meant that beryllium would be used to a greater extent than in the past (Drawing 13). Beryllium was used as a neutron reflector within the weapon. In 1958, when beryllium operations became a standard part of Plant operations, beryllium blanks were provided by an outside source and were milled, turned, drilled, and polished in Building 444 (ChemRisk, 1992:75). The trigger design remained roughly the same from 1958 to 1989, when the Plant ceased operations, with changes only in materials, quantities of materials, and dimensions.

After 1957, the primary mission of Building 991 shifted to shipping, receiving, and storage. Materials handled included special nuclear materials, classified materials, and other metal components. Most shipments were sent by rail until the mid-1970s, when specially designed tractor trailers (safe secure transports) were used. The safe secure transports were used for shipment of the final product by roadway. The underground storage vaults near Building 991 (996, 997, 998) were used to store retired weapons, sent by Pantex for recovery of plutonium and uranium, until they were taken to the 700-area buildings for recovery operations. Another vault, Building 999, was added to the existing three in 1956. Incoming materials were generally not unpacked in Building 991.

1964-89

The next large-scale change to the Plant came in the 1960s when the Atomic Energy Commission chose to make Rocky Flats the sole producer of triggers under the "single mission" concept. Previously a number of the nuclear weapons facilities had overlapping functions to provide redundancy in case of enemy attack or a labor strike. Hanford was manufacturing similar plutonium units and Oak Ridge similar enriched uranium components to those at the Rocky Flats Plant. Los Alamos also produced triggers on a small scale. Under the new arrangement, developed for economic reasons, each facility was to provide separate weapons components. As a result, the enriched uranium operations, including both manufacturing and recovery work, were transferred to Oak Ridge in 1964, and the trigger manufacturing was given solely to Rocky Flats. Production at the Plant increased dramatically.

Plutonium fabrication continued at an expanded level with production continuing in Building 776/777. By 1967, construction had begun on a new plutonium facility, Building 707, to augment operations at Building 776/777. By 1969, Building 707, a state-of-the-art facility, was finished. It was divided into eight modules, separated to minimize potential fire damage, each for a different operation (EG&G, 1992). A major fire in Building 776/777 in 1969 necessitated the relocation of some of its foundry, fabrication, and final assembly operations into the new Building 707. Building 707A was built in 1971 to handle these extra operations (EG&G, 1994:7-1). Final assembly operations remained in Building 707 until the Plant ceased operation (ChemRisk, 1992:79-80). Building 776/777 was cleaned, and used for machining, plutonium recovery, waste-related operations, disassembly and assembly, and testing operations. Much of the work became special-order or research and development operations (EG&G, 1994:9-9).

Building 771 was expanded in 1963-64 (771A), in 1967 (771B), and in 1971 (771C) to handle increased recovery operations. Building 774 continued to be used as a waste treatment facility. By 1968, new technologies had been developed for plutonium recovery from solid and liquid waste. A new recovery building, 371 was built based on more stringent Atomic Energy Commission standards than had been in use when 771 was constructed. However, it suffered from various design problems that prevented its opening until 1981 and caused termination of recovery operations in 1986. It never did become a fully operational recovery facility, and as a result, Building 771, planned to be closed in anticipation of the use of Building 371, remained in operation. Buildings 707, 771, and 776/777 remained as plutonium production buildings until 1989 when production ceased.

Finished triggers were taken from the 700-area buildings by truck under armed guard to a small shed near Building 551, where they were staged under guard for placement on specially configured atomic material transport railcars. Spur lines from the railroad came onto the Plant site from the southwest and curved up to run along the west side of Building 551. Building 440 was constructed in 1971 to modify standard freight cars for shipment of the triggers to the Pantex Plant in Texas, as well as waste materials to Nevada. Later the building was also used to modify standard tractor trailers into safe secure transport for shipping the triggers, making them tamper-proof. These unmarked safe secure transports were escorted by unmarked trucks and cars and drove the triggers to the Pantex Plant (SAIC, 1995). Building 991 provided a shipping and storage area.

When enriched uranium operations were transferred to Oak Ridge between 1964-66, Building 881 was shut down and decontaminated (ChemRisk, 1992:73). Side B of Building 883, formerly used for enriched uranium, was then used for beryllium rolling and forming (EG&G, 1992). In 1966, stainless steel operations were transferred from a vendor in Albuquerque, New Mexico and were located in Building 881. Stainless steel processing was done in Buildings 881 and 444 until Building 460 was constructed in 1984 specifically for all non-nuclear manufacturing. All stainless steel processing was consolidated in Building 460.

Over the years, since the addition of new fabrication and tooling in 1958 for hollow triggers, the manufacturing facilities and production processes did not change much, although they did move from building to building. The majority of the Plant expansion was driven by changes in weapons design, higher safety standards, and expansion of production (ChemRisk, 1992).

Transport of special nuclear materials was moved out of Building 991 between 1975 and 1976. During this time period, shipping occurred from Building 439/440. Because of security concerns, shipping was moved back to Building 991 after 1996. Incoming materials were generally not unpacked in Building 991. Site returns (retired weapons), however, were unpacked, tested, re-packaged, and shipped to Building 776/777 for disassembly. Other materials packaged and shipped included non-radioactive raw materials, partially finished products, purchase order items, non design agency special-order items, samples, instruments, and documents.

1989-92

The Resource, Conservation, and Recovery Act, regulating all aspects of the management of hazardous waste, became law in October of 1976. The Act made it illegal to improperly dispose of and handle hazardous waste. A conflict over hazardous waste jurisdiction at the Plant between the United States Environmental Protection Agency (USEPA) and USDOE ensued. In 1987-88, the courts confirmed that the USEPA had jurisdiction. The USEPA did not have access to the Plant and was convinced of wrongdoing by the USDOE.

During a routine inventory shutdown in December of 1988, glove boxes in Building 771 were cleaned with high temperature steam. The heat from this operation exited the building through the exhaust stack and a passing aircraft registered the hot spot on film. Believing that the incinerator was illegally being used during the scheduled shutdown, the USEPA used this opportunity to convince agents from the FB1 to issue a warrant to enter the Rocky Flats Plant and investigate the allegation. Although the allegation proved false, the investigation did uncover safety concerns at the Plant and ultimately led to the temporary suspension of plutonium operations at the Rocky Flats Plant in 1989.

The Plant contractor, Rockwell, was unable to comply both with their USDOE contract and the requirements of the Resource Conservation and Recovery Act and sued USDOE for statutory relief and release from liability. Rockwell stepped down as the contractor; EG&G was brought in to take over as operator of the site. The Plant remained closed for an extended period to allow the new operator to address the safety concerns (Buffer, 1995). In 1989, the Plant was added to the National Priorities List of contaminated sites to be remediated under the government's Superfund program (Thompson, 6 August, 1993).

Significant changes occurred at the site after the 1989 FBI investigation. Many outsiders were brought in to correct perceived safety problems. They expected to find a centralized chain of command; however, due to security reasons, there was no designated individual responsible for operations as a whole. Each separate process was operated independently of the others. Management of the Plant relied on process knowledge for day-to-day operations, rather than written procedures (Meyers, 1998 interview). A new cultural outlook and way of doing business was introduced, drastically changing the Plant operations and creating a tough transition period. With these changes, Secretary Watkins brought in a new system, which relied on written procedures and conduct-of-operations to document how work was to be conducted.

As non-nuclear operations continued, the primary focus at the Plant for the next 2 or 3 years was upon bringing the Plant up to current safety and operational standards, which had to be accomplished prior to a resuming nuclear operations and weapons production. Building 707 was the primary focus of the resumption efforts, so that the Plant could continue the W88 weapons program production (Wilson, 1998 interview). Buildings 701 and 559 were ready to resume production. The resumption plan caused the biggest turmoil the Plant had ever faced because it was forward looking, but most employees didn't know where it was going (Cunningham, 1998 interview). Contractors were brought in, mobile trailers set up, numerous procedures were written, and building drawings were redlined to show all the changes and modifications that had occurred over the years of intense production.

By 1991, a series of events worldwide, such as the fall of the Berlin Wall in 1989 and the breakup of the Soviet Union with the subsequent dissolution of the Warsaw Pact in 1991, reduced the Cold War threat and the need for a plutonium trigger manufacturing facility. In that year, United States President George Bush ordered all bombers and tankers to be taken off alert, and the Department of Defense began to reconsider its needs in terms of the size and nature of its military force. As a result of this reconsideration, the Department of Defense began cutting its military forces and cutting back on the production of new weapons. That same year President Bush also announced the cancellation of several nuclear weapons programs, including those that would have provided Rocky Flats with future work. In 1992, President Bush also canceled the production of the Trident II missile and its warhead (the W-88), the weapon that was the primary production program at Rocky Flats at the time. In 1992, the temporary suspension of nuclear weapons production, in place since 1989, was made permanent (Riddle, 1997 interview). Subsequently, Secretary Watkins publicly announced that the mission at the Plant would be changed to environmental restoration and waste management, with the goal of cleaning up and converting the Plant for new uses.

Public Perception of the Rocky Flats Plant

Through the 1950s and 1960s, employees were treated respectfully by most of the public. The public knew little about the work at the Plant, other than it was for military purposes. The public did know that in order to work at Rocky Flats, an employee had to undergo an intensive background search by the Federal Bureau of Investigations (FBI), and that employees were working for the security and freedom of the nation (Tesitor, 1998 interview). Public opinion of the Rocky Flats Plant began to change in 1969. Anti-nuclear, pro-environmental demonstrations, organized by Citizens Concerned about Radiation Pollution, began at the Plant after the 1969 fire in Building 776/777.

A strike between Dow and its union in 1970 added to the existing negative sentiment between the workers and the public. The public was led to believe that Dow continuing operations during the strike could place the city of Denver in danger. These allegations brought the Plant further into the public eye (Tesitor, 1998 interview). Activities associated with the strike, along with public dissent regarding the Vietnam War, began to alter the public's perception of and opinions regarding the Plant.

In 1975, a state task force appointed to study the Plant concluded that the siting of the Plant, with its inventory of plutonium and potential for nuclear accidents so close to the metropolitan area of Denver, had been a mistake. In the ensuing years, Jefferson County's Health Department Director, Dr. Carl J. Johnson, published reports allegedly linking plutonium contamination from the Plant to cancer and infant mortality. The first large protest at the Plant came in 1978, and included well-known activists Daniel Ellsberg and Allen Ginsberg. It was the first major protest at any USDOE plant. In 1983, protestors made an attempt to encircle the Plant, drawing thousands of people to the site. Over the years, some 1,500 protester arrests were made.

The Rocky Flats Plant was one of the most protested sites within the USDOE nuclear weapons complex. Plutonium was believed to be one of the most hazardous substances in existence, and Rocky Flats was known to use plutonium in its manufacturing processes. The protesters came from diverse groups, concerned with differing aspects of the United States Nuclear Weapons Program. Some were conscientious objectors to the Vietnam War, others objected to nuclear weapons production on moral grounds, while others objected to the use of their tax dollars supporting a program they didn't agree with or want. The Komitet Gosudarstvennoi Bezopasnosti (KGB), Committee for State Security, through a worldwide pro-socialist organization called the World Peace Council funded a number of anti-nuclear protests, marches, and demonstrations around the country (Tesitor, 1998 interview). Others worried about the health effects of nuclear weapon production, testing, and use, protested at the Rocky Flats Plant. Local citizens concerned about property devaluation also participated in protests at the Plant. In cases where towns grew up around facilities like Hanford, Savannah River, and Oak Ridge, the citizens were reliant on these Plants for their livelihood, and were sympathetic to them (Wilson, 1998 interview). This was not the case at Rocky Flats. In response to continuing protests, particularly a 1979 anti-nuclear rally that drew 10,000 participants, Rockwell employees at the Plant formed a grassroots organization, Citizens for Energy and Freedom, and organized a pro-nuclear rally, "Power for the People," that attracted 16,000 people (Young, May 8, 1992).

Many employees felt that the protesters were well intentioned, but misinformed. They found the protesters' conclusions to be erroneous. For example, the number of weapons in the stockpile were believed by the protesters to be the entire number of weapons ever produced, and did not take into account all the weapons that were retired and disassembled (Rothe, 1997 interview, Drawing 3). Most employees felt strongly that the world would be worse off without their efforts. Some employees came to despise the protesters, believing that to assist the enemy in United States' disarmament was treason, and if the communists took over the United States, 60 to 70 million people would die in the purges that would certainly follow (Thompson, 1998 interview).

Workers were proud of their national contribution, and were motivated through production goals and quality of work. The protests did not affect the workers' morale or the idea that their work was necessary to prevent the Soviet Union from launching an attack on the U.S. Most employees did not believe that if the United States threw away their weapons, the rest of the world would also do so (Hoffman, 1998 interview). During the Carter Administration (1976), President Jimmy Carter believed that if the United States took the first steps to stop nuclear weapons production, so would the Soviets. The Soviet stockpile increased dramatically during this time (Tesitor, 1998 interview).

In the early 1980s, the USDOE Albuquerque Field Office, then in charge of Rocky Flats, began a study of what the Rocky Flats Plant should look like in the year 2010. A 1988 report submitted to Congress indicated that the Plant's facilities were aging, waste storage and clean up was a major problem, and the public was opposed to the siting.

Some Plant employees believed that neither the protests nor the FBI raid caused the ultimate shutdown of the Plant. They believed the shut down was an economic, rather than a social decision. The late 1980s and early 1990s were a time of transition. The USDOE was considering consolidation of the Weapons Complex (Stakebake, 1998 interview). The Plant buildings were old and potentially a hazard. To keep the Plant operating would have required extensive remodeling and substantial funding. Even though weapons programs were scheduled into the mid- to late-1990s, the United States was entering into treaties with the Soviets, and many programs were zeroed-out for funding (Wilson, 1998 interview). The government was considering whether the capabilities of the Plant were still needed (Stakebake, 1998 interview).

Other Plant employees, however, believed that the protesters were successful in the complete closure of the site. The protests let the government know of the public's feelings toward nuclear weapons, and that Americans were no longer proud of their nuclear heritage. The Plant no longer had the support of local government and the public. These employees felt that the Secretary of Energy (Admiral Watkins) abandoned the Plant due to strong public opposition (Tesitor, 1998 interview). The last program, stainless steel operations, was transferred to Kansas City in 1995.

The Rocky Flats Plant was not the only facility within the United States Nuclear Weapons Complex that was shut down. All of the major facilities in the complex ceased nuclear weapons production in the 1980s. For several different reasons, the end of production was quite sudden and largely unexpected by most employees within a particular facility. Incidents of mismanagement and contamination at United States nuclear weapons sites led to a series of investigations into safety and environmental practices (USDOE, 1995:79). These investigations pointed out that most of the Energy Department's weapons plants were at or near the end of their design life. Many operations were discontinued while alternatives for weapons production were considered. During this general re-evaluation, the Cold War began winding down. With the collapse of the Soviet Union in 1991, the nuclear arms race of the Cold War came to an end, and with it the impetus to maintain the nuclear weapons complex in its entirety. As of this writing, final closure plans for the entire USDOE complex have not been determined. Facilities within the complex identified for total closure include Mound, Pinellas, Fernald, Hanford, and Rocky Flats. Other facilities will continue to operate in research and development, storage, and/or fabrication.

Manufacturing History

Plutonium Operations

Plutonium is a man-made transuranic metallic chemical element; it is not known to exist in nature. Plutonium, first discovered in 1941, is created from naturally occurring uranium that has been bombarded by neutrons in a production reactor. A complex chemical process is required to separate the newly created plutonium from the remaining uranium. The importance of plutonium to atomic weaponry is its highly fissile nature; it can undergo a fission reaction (which provides the force in a nuclear bomb) much more easily than uranium. However, due to its highly fissile nature, plutonium also has a higher potential of undergoing a spontaneous, uncontrolled fission reaction, also referred to as a criticality event. Plutonium occurs in two isotopes, plutonium-238 and plutonium-239. The plutonium-239 isotope is more highly fissile than the plutonium-238 isotope (Colliers Encyclopedia CD ROM, 1996).

The key to an atomic weapon is the use of fissile material. Plutonium was used to create the first-stage fission reaction (the trigger) which set off the second-stage reaction (the nuclear explosion). Plutonium is made in plutonium-production reactors at Hanford and the Savannah River sites. The fissile product from the reactors was processed through chemical separation plants to segregate the plutonium and uranium from other radioactive isotopes. Most of the plutonium from these plants went to Rocky Flats to be manufactured into weapons components. It was usually in the form of metal, but liquid and powdered plutonium was also produced. One of the reasons for the mystique of Rocky Flat was the use and alteration of raw materials to finished material. Unlike other areas, all of the manufacturing, technology, people, and skills needed to convert the raw materials into completed products was conducted at the Plant.

Recovery

The original plutonium recovery process was adapted from Los Alamos National Laboratory processes (Crissler, 1998 interview). The process was put into operation in May 1953 with the first shipment of plutonium nitrate solution from the Hanford Plant in Richland, Washington. Several years later, the Rocky Flats Plant also started receiving plutonium nitrate feed from the Oak Ridge Reservation. All of these shipments were discontinued in 1959. Since that time, internally generated plutonium residues from Plant operations were the primary feed for the recovery/metal production. Residues normally were solid materials varying in plutonium content from a few percent to almost pure plutonium metal.

The primary objective of the plutonium recovery process was the recovery of plutonium from all residues generated during plutonium-related fabrication, assembly, and research operations. The overall recovery process consisted of fifteen major operational unit processes including incineration, cation exchange, dissolution, anion exchange, batching and evaporation, precipitation, calcination, hydrofluorination, thermal reduction, leaching, oralloy leaching, chloride dissolution/chloride anion exchange/dicesium hexachloroplutonate production, molten salt extraction, salt scrub, and electrorefining (Drawing 10).

All incoming plutonium (either foundry-generated oxide or associated with production wastes) was dissolved in nitric acid solutions. Feed material was one of two types: a high-level material (plutonium oxide and impure metal) obtained from foundry casting operations, or low-level materials (residues produced in the recovery/manufacturing process).

The overall process and chemistry of plutonium recovery remained largely unchanged since recovery operations began. Prior to 1965, plutonium recovery operations were originally conducted in batch fashion that consisted of simple, manually operated equipment. At that time, batch operations were sufficient because the limited plutonium casting and machining operations generated little scrap. Similarly, site returns (retired or out-of-specification nuclear weapons or nuclear weapons components) were minimal.

To begin the recovery process, a mixture of nitric acid and plutonium residues was heated and agitated in a beaker inside a glovebox, to dissolve the plutonium into a nitric acid solution. In addition to being very labor intensive, the beaker method released fumes that corroded the electric heaters and caused problems for the glove box handling and filtration system. To improve dissolution, the beakers were replaced in 1965 with a system of continuous cascade dissolvers. Continuously operating and automatic control systems were later introduced to increase the recovery capacity of the facility and to decrease radiation exposure of operating personnel.

During the continuous cascade process, steam coils were immersed in the liquid nitric acid solution. The resulting slurry overflowed from the first through the last dissolver in the set. From the last dissolver, the slurry overflowed to a horizontal-pan vacuum filter, which separated the undissolved solids from the solution. The plutonium solution then went to ion exchange process. Solids were scraped from the filter, dried on a hot plate, and packaged for removal from the glove box for treatment and disposal.

After the plutonium was dissolved, the other elemental impurities were separated out of the solution. The plutonium feed was purified by solvent extraction, later replaced by the anion exchange process. The plutonium nitrate solutions were pumped through glass columns, containing anion exchange resin. The anion exchange process purified and concentrated plutonium-bearing nitric acid solutions to make them acceptable as feed for conversion to metal. The solution was concentrated in a steam-heated, natural-convection evaporator. The concentrated solution, called bottoms, was transferred to tanks.

Relatively pure plutonium nitrate solutions received from oxide dissolution, anion exchange, and feed evaporation were blended and adjusted to the proper pH and plutonium concentration before entering the peroxide precipitation process. Feed for the peroxide precipitation process was prepared in batches by blending the available solutions in the proper ratios.

The peroxide precipitation process converted the plutonium in solution to a solid form and achieved some purification of the plutonium from metallic elements, notably americium. The feed solution was pumped into a refrigerated, stirred reactor called a digestor. Hydrogen peroxide solution was fed into the digestor. Precipitation occurred in the digestor and crystal growth occurred. The plutonium peroxide slurry cascaded through the digestors and into the rotary drum filter basin. Vacuum applied to the filter removed the liquid, causing the plutonium peroxide to collect on the filter surface. The plutonium peroxide cake collected on the rotary drum was cut off the filter wheel, collected in containers, and transferred to the calciner.

The calcination process converted plutonium peroxide to plutonium oxide and drove out residual water and nitric acid, leaving a dry, powdered product. The dried cake was collected, screened, and weighed in batches. Every third batch was sampled and analyzed for impurities for process control. Batches were stored in approved containers in racks in the glove box while awaiting hydrofluorination.

Plutonium oxide was converted to plutonium tetrafluoride in a continuous rotary-tube hydrofluorinator. The plutonium tetrafluoride product was collected, weighed, and transferred in batches to the reduction process. The hydrofluorination process produced high neutron radiation, which emanated from plutonium tetrafluoride.

Plutonium tetrafluoride produced by the hydrofluorination process was reduced in batches to plutonium metal by interaction with calcium metal in an induction-heated reduction vessel. The vessel was heated until the reduction reaction took place, producing plutonium metal and slag. The resulting plutonium metal button was separated from the crucible, sand, and calcium fluoride slag. It was cleaned, sampled, and packaged for storage until the analysis was complete, and the button was sent to fabrication (Photographs 83-31 and 83-K-17).

Fabrication

At Rocky Flats, plutonium buttons from the plutonium recovery process were first cast into ingots (Drawing 9). The casting operation created feed ingots and War Reserve ingots of plutonium metal. The first casting process created the feed ingot. Materials used for the creation of feed ingots included plutonium buttons from recovery processes, briquettes, and scrap plutonium metal. Production control personnel used sampling data to calculate the precise feed ingot mixture which would produce a War Reserve ingot of specific purity from the second casting. The casting process consisted of weighing the metal, placing it in tantalum crucibles, and melting it in one of four electric induction furnaces. Molten metal was poured into molds to form ingots. The War Reserve ingot was used to fabricate weapons components. Samples were taken to verify the chemical makeup and purity of both the War Reserve ingot and the fabricated component.

Plutonium War Reserve ingots were rolled, formed, and heat-treated, and then were cut in a blanking press. Cut blanks were sent to thermal treatment (annealing and homogenizing). Following thermal treatment, blanks were formed into hemi-shells (1/2 shells) in a hydroform press. After forming, the parts were annealed and measured on a density balance.

The hemi-shells went to final machining involving lathes, mills, a drill box, a high-precision drill press, and a hydraulic press. Each part was then marked with a serial number, cleaned, weighed, and inspected. Plutonium parts were welded, then inspected for leaks. Parts were assembled into subassemblies, then into assemblies, and then assembled into triggers. Assembly included such operations as machining, cleaning, matching parts, brazing, welding, heating under vacuum for trace contaminant removal, marking, weighing, monitoring for surface contamination, and packaging for shipment. The assembled triggers and parts were subjected to final processing steps, final testing, and inspection, then stored to await shipment.

Depleted Uranium Operations

Naturally occurring uranium ore consists of approximately 1% uranium. That uranium is composed of three isotopes: U-238 (99.28%), U-235 (0.71%), and U-234 (0.01%). Depleted uranium results when the more highly fissile isotope U-235 is isolated using a complex chemical separation process. After removal of the U-235, the resultant material is referred to as "depleted" in that isotope. Depleted uranium consists almost exclusively (99.8%) of the U-238 isotope, which, although it has low radioactivity, is not considered to be very fissile (i.e. able to undergo a fission reaction). U-238 is a very dense, very hard, heavy metal, and shares the toxic properties of other heavy metals when ingested, inhaled, or injected.

Depleted uranium was used as a non-fissile component in the trigger design (Drawing 13). Uranium, nearly twice as dense as lead, was also machined at the Plant into sheets used as in military tank armor, using its hardness to provide additional protection from artillery shell penetration. From 1951 until 1955, depleted uranium was shipped to Rocky Flats as derby-shaped parts from Paducah, Kentucky and later as ingots from the Feed Materials Production Center in Fernald, Ohio.

Uranium was cast in the foundry into near-net shapes (close to the final product form) and then sent to machining. Induction-cast depleted uranium, arc-cast depleted uranium, depleted uranium alloy ingots, beryllium ingots, and aluminum shapes were produced in the foundry. The metals were placed in crucibles, loaded into one of eight induction furnaces, and melted in a vacuum atmosphere. Induction casting used radio frequency energy to melt the metal, which was poured into graphite molds to form ingots.

Metal parts containing depleted uranium, depleted uranium alloy, and depleted uranium with traces of iron, silica, titanium, aluminum, or stainless steel were cut in the depleted uranium machining process. Machining operations included turning, facing, boring, milling, and sawing.

After 1956, the uranium ingots were processed into rolling pucks, then rolled and formed, and final machined. The depleted uranium ingots or billets were hot rolled and formed into parts or combined with niobium to form binary metal. Virgin depleted uranium ingots were weighed, immersed in a salt bath, rolled into a sheet, and sheared to length. The sheets were annealed in a second salt bath, cooled, and cleaned in water. The sheets were sheared a second time and trimmed to final length into electrode strips. The electrode strips were bent, cleaned in acid, and welded in a box configuration. Electrode filler strips were rolled, punched for boltholes, and cleaned in acid. Final assembly operations were conducted in Building 991, 777, or 707, depending on the time frame.

Recycled depleted uranium ingots were weighed, cropped, re-weighed, and heated in a salt bath. The ingots were rolled and sheared to length; the sheets were annealed, cooled, and cleaned in water. They were then sheared, cut into discs, heated, and formed into parts. A second forming, called a re-strike, was done to insure proper size.

Depleted uranium recovery operations were not conducted at the Plant.

Enriched Uranium Operations

Enriched uranium is valued for its fissile nature (i.e. its ability to undergo a fission reaction), and is a primary ingredient in nuclear weapons and nuclear power reactors. It is created from naturally occurring uranium, which consists of three isotopes: U-238 (99.28%), U-235 (0.71%), and U-234 (0.01%). Using a complicated chemical separation process the U-235 isotope is isolated and the concentration is raised to more than 90% (from an original concentration of 0.71%). The resultant enriched uranium is highly fissile.

Enriched uranium was one of the materials used to create the first-stage fission reaction. It was possible to make nuclear weapons either by using plutonium or uranium. The "Little Boy" bomb dropped on Hiroshima was a uranium-type bomb, although most modern atomic weapons used both plutonium and uranium.

Fabrication

The original trigger design required a large amount of enriched uranium. The primary operations at the Plant included fabrication support, which included the foundry for casting of shapes and ingots; machining and inspection; metal product support, which included recovery of relatively pure materials; and salvage support, which handled recovery of solutions and solid residues with relatively low enriched uranium content.

Processes used at the Plant were based upon those developed at the Los Alamos Scientific Laboratory and the Oak Ridge Reservation, during and after World War II. The processes were refined at the Oak Ridge Reservation Y-12 Plant in the several years preceding the construction of the Rocky Flats Plant, although many improvements to the process and equipment were made by Plant personnel.

For the first months of operations, uranium castings were received from the Oak Ridge Reservation in the form of hockey-puck-sized buttons. Once recovery operations were established, uranium buttons produced at Rocky Flats were added to the feed material. In the casting process, uranium metal was placed in a crucible, heated in bottom-pouring induction furnaces, and then poured into graphite molds. Machining operations, including rolling and forming, and computer controlled turnings took place in Building 883 or the 881 Annex.

In 1964, enriched uranium operations at the Plant began phasing out with the advent of the Atomic Energy Commission's single mission policy. Production of enriched uranium components ceased at the Rocky Flats Plant in 1967, when the Y-12 Plant at the Oak Ridge Reservation assumed sole responsibility. From 1964 to 1966, plutonium production became the focus of operations at the Plant.

Recovery

Enriched uranium recovery operations were initiated shortly after fabrication operations began. Several different recovery operations were used, depending on the type of initial material. Uranium recovery involved both slow and fast processes. The slow process involved placing relatively impure materials with low concentrations of uranium into nitric acid for leaching and solvent extraction. Impure materials such as slag, sand, crucibles from the foundry operations, and residues from the incinerator were reduced via the slow process. The materials were crushed into pea-sized feed in a rod mill and placed in various dissolving tanks containing nitric acid. Solutions from the dissolution filters were concentrated in three-story-high solvent extraction columns. The solution was then pumped into various evaporators for further processing.

The fast process handled materials that were relatively pure, including uranyl nitrate, and used conversion and reduction steps to produce a pure uranium button. Materials such as chips from machining operations and black skull oxide contained fairly high percentages of enriched uranium that were easy to convert into pure uranium buttons. Chips and skull oxides were burned to form uranium oxide and then transferred for dissolution in small batches of concentrated nitric acid. The dissolution room housed three rows of controlled hoods known as B-boxes (similar to laboratory hoods). These boxes operated with high air velocities at their openings to ensure that the vapors were contained within the hood. The dissolution process yielded a uranyl nitrate solution, from which uranium peroxide was precipitated. Once filtered, the precipitate formed a yellow cake, which was heated to produce an orange uranium oxide. The dissolution, precipitation, and calcination processes were originally performed as batch processes. By the late 1950s to early 1960s, the process became a continuous operation. The orange oxides were converted to uranium tetrafluoride, a green salt. The green salts were transferred for final reduction to uranium metal.

Beryllium Operations

Beryllium is an alkaline metallic chemical element. Elemental beryllium is a light, steel gray metal; it is very hard and very brittle. Pure beryllium at high temperatures is very ductile, and can be rolled into sheets. The primary use for beryllium in the nuclear weapons program is as a neutron moderator or reflector (Drawing 13). It emits neutrons when bombarded by alpha particles. Another use of beryllium is as an alloying agent, where it imparts a highly tensile strength.

Rocky Flats began production scale operations in 1958, with the newer trigger design. Beryllium was used as a neutron reflector in the trigger design. At room temperatures the material was extremely brittle and required unique handling techniques.

Production operations initially involved only the machining, final inspection, and assembly of beryllium parts which were supplied by an off site vendor. By the mid-1960s, Rocky Flats beryllium operations also included the casting and shaping of beryllium parts to the proper dimensions. By 1975, foundry casting of beryllium on the Plant site had ceased with beryllium supplied in the form of blanks from an off site contractor. Machining of beryllium parts continued in Building 444 until production shut down in the late 1980s.

The "wrought" beryllium process was developed in approximately 1962 through research and development work at Rocky Flats and other USDOE facilities. This process involved casting beryllium ingots, sawing the ingots, "canning" (encasing) them in stainless steel, rolling them into sheets, and cutting the cans away. The beryllium ingots were very brittle, and in order to roll them they had to be encased in stainless steel and heated to a temperature ranging from 900 to 1,000 degrees centigrade. After the stainless steel can was removed, the beryllium sheet was then cut into shapes.

Beryllium machining processes involved sawing, milling, drilling, and lathe operations followed by polishing and abrading operations. Site returns (retired weapons) and components containing beryllium were also returned to the machining area for dismantling. During the Plant's operations, machining has included work on beryllium casings, wrought processing, sintered forms, and bar stock.

Other than the recycling of parts from site returns (retired weapons), beryllium recovery operations were not conducted on the Plant site. Some beryllium-related waste management activities were conducted in Building 447.

Stainless Steel Operations

Stainless steel is created from an alloy of steel with chromium to create a durable material highly resistant to oxidation. With the nuclear weapons production program, stainless steel had many uses. One of the primary uses for stainless steel at the Rocky Flats Plant was the manufacture of the tritium reservoir, and tritium delivery system components. Tritium was used to aid in the second stage fusion reaction of the later weapon designs.

When enriched uranium operations were phased out at Rocky Flats in the mid-1960s, factors including favorable economics and considerable floor space in Building 881, led to the decision to begin stainless steel machining (Drawing 12). The phase-in of stainless steel machining work began in Building 881 in 1966. All stainless steel work on the Plant site was done in that building by 1968. In 1967, Dow, the site contractor at the time, acquired the J-line (code name) stainless steel activities. Stainless steel machining work was previously conducted by American Car and Foundry Industries, located in Albuquerque, New Mexico. Stainless steel work was conducted in Building 881 from 1968 to 1984. In 1984, machining was moved to Building 460, a facility specifically designed for stainless steel machining operations.

Stainless steel casting, forging, or recovery operations were not conducted on a production scale at the Plant. Stainless steel was used primarily to make the reservoirs that held tritium gas within the bomb. Other stainless steel work included fabrication of the tubes and fasteners associated with the tritium reservoir-to-trigger delivery system.

Production operations included machining, assembling, inspection and testing, and support. Depending on technical requirements, methods, and/or equipment needed, the sequence of operations was altered to meet specific project needs. Conventional tools, such as lathes, mills, borers, and presses were used in machining operations. The machined parts were cleaned and inspected prior to being sent to the assembly area. Assembly operations included cleaning, matching, brazing, welding, inspection, testing, and packaging. The parts were then assembled and joined by brazing or welding. Although stainless steel recovery operations were not conducted at the Plant, scraps and turnings were generally collected for resale to an off site recycler.

Assembly Operations

Plutonium, enriched uranium, depleted uranium, beryllium, and stainless steel components fabricated on site, along with components manufactured from Hanford and Oak Ridge, were assembled into final products, inspected, tested, and placed back in storage prior to off site shipment. Because all of the radioactive components were coated in nickel or encased in plastic, assembly of the early concept design products was conducted in open rooms, not in enclosed glove boxes.

In 1957, production began on a new weapon design, requiring changes in the amount of materials used in the trigger, the amount of machining and handling required, and the need for tighter tolerances. Because of the new design, final trigger assembly took place in the newly constructed Building 776/777. Assembly of older uranium-based weapons continued in Building 991 until the 1960s. A limited number of plutonium-based triggers were also thought to have been assembled in Building 991 during the early 1960s.

Major Material Processing Buildings

(Note: The HAER documents indicated provide a more detailed description of the buildings and building operations.)

Depleted Uranium and Beryllium - Building 44/444 (Plant A) (HAER No. CO-83-L)

Building 444 was one of the first buildings constructed at Rocky Flats. Beginning in 1953, depleted uranium was both cast and machined in this building. The original building contained the foundry, depleted uranium machine shop, beryllium machine shop, heat treating shop, plating laboratory, carbon machine shop, casting shop, tool grinding shop, welding and brazing shop, pressure and leak testing laboratories, precision measuring laboratories, building maintenance shop, and parts of the precision shop and non-destructive testing laboratory. Some of the former production areas were later used for storage of excess tools and materials.

From 1952 until the end of production, beryllium and depleted uranium casting, machining, cleaning and inspection equipment were housed in Building 444. Depleted uranium was cast into near-net (close to final product) shape in the foundry and then sent to the machine shop. Prior to the construction of Building 883, casting and final machining took place in Building 444. After 1956, the uranium and beryllium ingots were processed into rolling pucks and shipped to Building 883 (Side A) for rolling and forming.

Enriched Uranium, Non-Plutonium Metals/Alloys (Beryllium and Stainless Steel) - Buildings 81/881, 883, 865, and 460

Building 81/ 881 (Plant B) (HAER No. CO-83-Q)

Building 881 was one of the four original manufacturing buildings that comprised the Rocky Flats Plant in the early 1950s and was the fourth building to come on line. Beginning in 1953, this structure housed the Plant's only enriched uranium component manufacturing and recovery operations. The original purpose of Building 881 was the processing and machining of enriched uranium into finished weapons components. The enriched uranium process included chemical recovery operations and foundry equipment. A large part of the early work at the Plant took place in this building, because the triggers required a large amount of enriched uranium. The primary operations were divided into the following areas: fabrication support, which included the foundry for casting of shapes and ingots; machining and inspection; metal product support, which included recovery of relatively pure materials; and salvage support, which handled recovery of solutions and solid residues with relatively low uranium content.

Building 881 operations represent three distinct primary functions: enriched uranium manufacturing and recovery (1952-66); stainless steel operations (1966-84); and recent activities that have taken place in the building since manufacturing operations were phased out, including research and development, laboratories, and computer administration.

Building 881 is an irregularly shaped, multiple level structure that is built into the side of a hill. Building 881 is considered to be a three story structure with mezzanine levels on the first and second floors. The complex encompasses approximately 245,000 square feet. During the period of uranium and stainless steel production, most of the production related activities occurred on the second floor.

Building 883 (HAER No. CO-83-R)

Building 883 was constructed in 1957 to accommodate fabrication of enriched and depleted uranium and beryllium parts. The sealed, hollow shape of the weapons components required a significant amount of rolling and forming of both types of uranium. Because space in the existing Buildings 881 and 444, (enriched uranium and depleted uranium parts manufacturing) was inadequate, Building 883 was constructed to handle some of the uranium and beryllium rolling and forming operations.

Building 883 is a high bay, single-story building with a 38' ceiling. The majority of the building's area is contained in a high bay metal working area. Eighty percent of the area of the building has been used for metal processing.

The processing areas on the first floor were referred to as Sides A, B, and C. The building was originally designed with two functional areas or sides to prevent cross contamination of radioactive enriched uranium with non-fissile depleted uranium. Side A housed equipment used for rolling, pressing, and shearing of depleted uranium and beryllium operations. Side B housed equipment used for rolling, pressing, and shearing of enriched uranium. Side C, completed in 1985, supported acid scrubbing operations and tank armor plate production.

Building 865 (HAER No. CO-83-AA)

Building 865 was built in 1970 to house metalworking equipment for the study of non-plutonium metals and the development of alloys. The building contained shops and equipment that supported metal fabrication, machining, and processing for both production and development in metalworking. The building conducted metallography laboratory work and decontamination activities for product research and development. The building contained equipment for rolling, shearing, forging, extruding, swaging, grinding, pressing, heat-treating, vacuum induction casting, and vacuum casting. A number of metals were processed and fabricated into prototype hardware.

All metalworking operations were conducted in the high bay area. The metal was heated in electrical resistance furnaces and transferred to the steam hammer for forging. When beryllium and uranium were forged, permanent hoods were used to create airflow from the workplace and exhaust away from the operator. Beryllium, uranium, steel, and other ferrous and nonferrous metals are press-formed (hot or cold) into the desired shapes.

Building 460 (HAER No. CO-83-T)

Building 460 was built in 1984 to house equipment, systems, and personnel for fabrication, assembly, and testing of stainless steel components such as reservoirs, tubes, and non-fissile trigger components. The facility was described as the most modern non-nuclear manufacturing building in the USDOE Nuclear Weapons Complex.

Total area of the building is approximately 230,000 square feet, split between the first floor and two second-floor mezzanines. All non-nuclear manufacturing at the Plant was consolidated into this one facility. The stainless steel operations conducted in Building 881 and some non-nuclear metalworking operations from Building 444 were transferred to Building 460 after its completion. Manufactured components were associated with the tritium reservoir-to-trigger delivery system. Operational processes included fabrication, assembly, and inspection. Fabrication of stainless steel and other non-nuclear metal parts included mechanical machining, electrochemical machining and grinding, electric discharge machining, and crush grinding.

Plutonium - Buildings 71/ 771, 776/777, 707, 371

Building 771 (Plant C) (HAER No. CO-83-N)

Building 771 was originally constructed as a totally self-contained plutonium fabrication and recovery facility. For the period of May 1953 until 1957, when Building 776/777 entered operation, Building 771 was the sole plutonium facility at the Plant. During this time period, the building housed plutonium parts production-related activities, including casting, fabrication (machining), coating, inspection, testing, and recovery operations; the chemical and physical operations for recovering plutonium and refining plutonium metal; plutonium chemistry and metallurgical research operations and radiochemical analytical laboratory operations; storage of plutonium metal; various laboratories; and other support operations.

The original Building 771 is a two story structure built into the side of a hill with most of three sides covered by earth. The fourth side, opening to the north, provides the main entrance to the building. The plutonium-related operations were arrayed along the southern hallway of the first floor. Plutonium manufacturing operations were located on the south side of the hallway, while plutonium recovery operations were located on the north side of the hallway. Since completion of the original building, six major additions have been constructed.

By the mid-1950s, the space within Building 771 was inadequate to support all plutonium operations needed at the Plant. A new weapon design required more plutonium than that of the original weapons. Additionally, the new weapon design required more machining to achieve the necessary plutonium shapes. An increase in plutonium recovery operations was expected, partly due to the new weapons design. A new major production building, Building 776/777, was built to support the casting and fabrication operations. On September 11 and 12, 1957, a fire occurred in a fabrication line in Building 771. The fire damaged Building 771 and caused radiological contamination, resulting in an estimated property loss of $818,600 (Buffer, 1995). Many of the plutonium operations were moved to Building 776/777 after the fire. The fire debris had been cleaned up by 1958. Much of the production and fabrication equipment remained in Building 771 to provide backup plutonium production capabilities for the Plant. From 1957 onward, the mission of Building 771 focused primarily on plutonium recovery.

Building 776/777 (HAER No. CO-83-O)

As a result of the design changes and increase in workload, Building 776/777 was constructed for plutonium casting, fabrication, and assembly, and quality assurance testing. The main function of the 776 side of Building 776/777 was the casting and fabrication of plutonium parts. The main function of the 777 side of Building 776/777 was assembly of parts and some disassembly of site returns (weapons returned to the site for retirement, upgrade, or reprocessing).

The original foundry was located in the southwest corner of Building 776/777. The foundry contained sixteen furnaces, which were crowded into the room. Foundry operations cast plutonium, either as ingots suitable for rolling and further wrought processing or into shapes amenable to direct machining operations. Fabrication operations involved either direct machining of ingots or cast shapes or conducting the wrought process, which further prepared the ingot for machining operations. The wrought process involved rolling the ingots into sheets and cutting them into circular-shaped blanks to be passed through a press. The pressed blanks were then annealed and machined. Machining involved taking the cast or wrought part and debrimming or removing spurs, contouring, drilling, and milling. Machining operations took place on the North-South-East Line.

Assembly operations involved assembling trigger components. The units primarily contained nuclear materials such as plutonium and uranium; however, non-nuclear materials such as beryllium, steel, copper, aluminum, and silver were also assembled. Assembly activities included drilling, welding, brazing, turning, and polishing. After assembly, complete units were packed and shipped off site or to Building 991 for final processing, storage, and shipping.

The first weapons disassembly (site return) work was performed in the 777 side of Building 776/777 in 1958. Increased site-return disassembly activities began in the late 1960s, as old weapon designs were retired and disassembled to recover valuable materials. After disassembly, parts were inspected for unusual conditions and segregated according to material type. Plutonium materials were returned to the 776 side of the building's foundry where they were cast into feed ingots. Depending on assay specifications, the ingot was then sent to the molten salt extraction facility for americium removal. Otherwise, the ingot was sent to Building 771 for chemical purification and returned to the foundry as a fresh button. Enriched uranium parts went to Building 881 for recovery, and depleted uranium and inert components were packaged for disposal at off site disposal sites.

On May 11, 1969, a fire occurred in Building 776 from the spontaneous ignition of a briquette of scrap plutonium. The fire resulted in $26.5 million in property loss, loss of production capabilities, and the decontamination took two years to complete. The incident resulted in many new safety features including installation of water sprinklers and firewalls to control the spread of fire, and the use of inert atmospheres for plutonium operations to prevent fire propagation from occurring.

After the fire, the majority of the foundry and fabrication operations were transferred to Building 707. After several months of cleanup, limited production operations resumed in Building 776. The main operation conducted in Building 776 became waste and residue handling, although operations such as disassembly of old weapons (site returns) and special projects continued in the building. Processes conducted in the building included size reduction of large scrap equipment, pyrochemistry, coating operations, and test runs of a fluidized-bed incinerator unit.

Building 707 (HAER No. CO-83-M)

Building 707 was the primary plutonium fabrication building from 1970 until production ceased in 1989. After two destructive fires in other plutonium production buildings (Buildings 771 and 776/777), the design of Building 707 incorporated extensive control and safety features, including the first-time use of inert atmosphere in the glove boxes. Construction of Building 707 began in 1967 with plutonium operations commencing on May 25, 1970. Building 707A was built in 1971 to accommodate operations moved from Building 776/777 as a result of the fire in Building 776.

Operations in Building 707 included metallurgy, parts fabrication, assembly, inspection, and non-destructive testing. The main floor of Building 707 was compartmentalized into eight side-by-side modules (A through H) which contained one or more of the primary production operations. Each module was 140' x 49' with an area of approximately 6,860 square feet. The modules were arranged from the north side of the building to the south. The main floor of Building 707A was divided into two modules, Modules J and K, which contained plutonium foundry operations and two plutonium storage vaults. One storage vault, on the north end of Module K, was equipped with a remote controlled, computerized retriever (the X-Y retriever) for handling plutonium stored in the vault. The general flow of work and materials was from Modules J, K, and A sequentially to Module H.

Building 371 (HAER No. CO-83-K)

Building 371 was originally built to accommodate the plutonium recovery operations from Building 771, using advanced technology for plutonium handling, recovery, and safety. Although fundamentally based on the processes and principles developed previously in Building 771, the design of Building 371 incorporated many technological advances and refinements. The design, initiated in 1969, was far more sophisticated and complex than any others at the Plant; Building 371 was designed to emphasize automatically controlled, remotely operated processes, as contrasted with the direct, hands-on operations in Building 771. The operations for the building focused primarily on recovery of plutonium from both solid and liquid wastes. The final product from the process operations was intended to be recycled plutonium metal, which was to be reused in the Plant's primary manufacturing process.

Operations in Building 371 were threefold: recover plutonium from all residues generated by plutonium-related fabrication, assembly, and research activities throughout the Plant; convert the recovered plutonium into high-purity metal buttons; and recover associated americium and convert it to americium dioxide, a saleable product.

Building 371 was originally scheduled for completion in 1976 at a cost of approximately $70 million. The project was plagued with schedule overruns and construction material substitutions. The stacker-retriever, a remotely operated, mechanized transport system for movement of plutonium storage drums, became operational in 1976. In 1978, the waste treatment process came on line. In 1980, the heating, venting, and air conditioning systems were brought on line. The rest of the building was finally completed in 1981 at a total cost of approximately $214 million.

In 1982, pilot-scale aqueous plutonium recovery operations began in Building 371 (Photograph 83-K-17). There were not enough operators to run the process continuously, so the process was run in batches, shutting down one phase to start the next. Employees were to be transferred to the new facility when it was fully operational and recovery operations in Building 771 were shut down.

One year after the aqueous recovery process began, the USDOE conducted a plutonium inventory at the Plant. The Building 371 inventory was difficult to quantify. The building had over 770 miles of piping, of which, 70 miles were plutonium process lines. Process lines ran through walls and traversed several floors. In the 1960s, personnel associated with safeguards and security were primarily concerned with the amount of material that went into the process and the amount that came out; the amount currently residing in the process was only estimated. By 1976, accountability was required for every gram of material at all times. The aqueous process was shut down until all in-process plutonium could be located. The majority of the material was found. Designed in 1968, Building 371 was not constructed to meet this type of safeguard and security requirement. Although several projects to upgrade the system were proposed, none were approved. The aqueous process, which never ran at full capacity, was not operational after 1983.

Shipping/Receiving, Assembly -Building 91/ 991 (Plant D) (HAER No. CO-83-U)

Building 991 was the first building to be completed at Rocky Flats. It was designed for shipping and receiving and for final assembly of weapons components. Administrative services for the Plant were also carried out in Building 991 until Building 111 was completed.

In addition to the handling of materials, a number of research and development projects were conducted in the building. These included: radiation studies conducted from the 1960s-70s; a beryllium coating process from 1964-76; and an explosives-forming project from 1966-74. Most special projects and research and development operations were moved out of the building by 1976.

Building 991 was primarily used for off site shipping of components, assemblies, and other materials associated with past weapons and/or plutonium metal production. The building also housed non-destructive testing operations and other support operations.

Building 991 was used to test the quality of non-nuclear raw materials and parts fabricated by off site vendors and to inventory and store parts for future use. Building 991 took over storage operations from Building 881 in the 1970s. To insure the quality of the off site materials, a metallography lab was used. In the late 1980s, the handling of non-classified materials was moved to Buildings 130 and 460. Non-nuclear materials ready for assembly were sent directly to Building 460.

Security *(HAER No. CO-83-V, CO-83-G, CO-83-X, CO-83-Z, CO-83-T, CO-83-H, CO-83-I, CO-83-D, and CO-83-J)*

Indicative of the importance of security, the first structure on site was a small guard shed building in mid-May 1951 (Drawing 17). In comparison, excavation for the first permanent building on site, Building 91, did not begin until July 10, 1951. The Plant was surrounded by 10 miles of barbed wire fence, electric fence, and livestock fence, and armed guards patrolled the perimeter of the Plant. Each of the four lettered plants had its own guardhouse: Building 446 for Plant A; Building 864 for Plant B; Building 773 for Plant C; and Building 992 for Plant D. Building 121 and firing range were constructed for the security force as part of the original Plant. As new production buildings were constructed, individual guardhouses were also constructed for them. Guardhouse 888 was built in 1964, close to the criticality laboratory (Building 886); Guardhouse 461 in 1985, for the stainless steel fabrication plant (Building 460).

Facilities considered to be part of the security force included: Building 119; Building T120A; Building 121; Building 128; Buildings 987 and 993 (munitions storage); Buildings 100, 120, 900, and 920 (personnel access control points); Buildings 372A, 372, 762A, 763, 792A, and 792 (major access control points); Buildings 113, 133, 446, 461, 557, 773, 864, 888, and 992 (guard posts); and Buildings 375, 550, 761, and 901 (guard towers).

Security of the Plant included control of access; preparation for and prompt response to threats or acts of violence; screening of future employees, including a 15-year background check for Q clearance; inventory control of government equipment; and procedures for handling breaches of security. The Atomic Energy Act (Section 161.k) authorized security personnel to carry firearms and arrest without a warrant in order to safeguard the special nuclear material from theft and to keep citizens and workers from harm. This authorization included the use of deadly force, when necessary.

The first security chief at Rocky Flats Plant was James A. O'Brien, a former narcotics and Army intelligence officer. According to a former security director, in the early years, security was concerned with the Cold War, espionage, and the secrecy associated with building nuclear weapons. It was important to safeguard design secrets, and later, the numbers of weapons being produced. Classified information was available only on a need-to-know basis; employees received instruction only on their specific duties. All employees were required to have a Q clearance, a top-secret level for atomic workers requiring a 15-year background check. Employees were forbidden to talk about their work with anyone (Kennedy, 1994:16; Young, 8 May 1992). Employees at the Plant were unaware of the duties of family members also employed at the Plant. There were many instances of immediate family members working at the Plant, with no knowledge of what the other's job duties were.

Cold War fear ran rampant during the early 1950s through the late 1980s, possibly bordering on paranoia. Employees' backgrounds were thoroughly checked; rooms were monitored for bugs prior to meetings being held; information was compartmentalized. Production information was shared only on a need-to-know basis. Secrecy was a key component of site security. Off site, employees were only allowed to say where they worked and their official labor title (Weaver, 1998 interview). The secrecy was part of everyday life: no one asked for or offered information; most workers did not consider it a drawback, just a fact of working at Rocky Flats.

Very few employees knew what the final product was that was being shipped to Pantex, nor did they consider it important to know what the final product was (Weaver, 1998 interview). Most employees were cleared for work only in the area or building to which they were assigned, and did not know what operations occurred in other buildings or areas. They were required to have a separate badge for each area they entered (*Rockwell News,* 1983). Workers parked outside the Plant area, at the west end (the sole entry point), and were bused to Building 111, where they checked in at the clock room, and then went to their own buildings. A small bus stop (114) was built in the administrative area. By the mid-1950s, cars were allowed onto the site. A guard post, Building 100, was built at the west access road in 1969 to check traffic. By 1964, an east access route off Indiana Street had been built, with guardhouse Building 900.

Secrecy was also extended to the guards; they were not well informed as to what was to be protected. Guards were not given information regarding what to protect within individual buildings; they also worked on a need-to-know basis, gathering knowledge and information from walking the floor. It was not until the mid-1980s that the security force was formally trained on the nature of the materials that they were to protect (Cunningham, 1998 interview).

Formal security sanctions were imposed. The first warning for a security infraction was verbal, the second was written, the third required time off, and the penalty for the fourth infraction was termination (Weaver, 1998 interview). Informal sanctions included embarrassment and ridicule from co-workers. In one group, an eight ball (from a billiards game) was circulated. If someone was written up, the eight ball had to sit on the desk of the division manager as a constant reminder until someone else was written up and the ball was passed on (Riddle, 1997 interview).

Security infractions were considered big events at the Plant: people believed in what they were doing and simply did not talk about their individual assignments or the Plant in general (Richey, 1998 interview). Signs were posted on the outer gates with the number of infractions that had occurred. When one occurred, an investigation took place immediately, and the sign was updated regarding the outcome. Since the Plant community was extremely tight, any infraction was considered a social stigma (Cunningham, 1998 interview).

During the Manhattan Project, plutonium was also referred to as "copper." If someone was really talking about copper, it was called "honest-to-god copper" (Rothe, 1997 interview). Continuing the practice of using codes, words such as plutonium, uranium, or americium were not spoken at the Plant. Instead, code words like "X," "Y," or "Z" were used. Depleted uranium was also known as tube alloy, carried over from British terminology, and enriched uranium was also known as oralloy (Oak Ridge alloy).

In the 1970s and 1980s, security was concerned less with espionage and more with the threat of terrorism and infiltration of the Plant by protesters. Better protection of the outer boundaries of the site became necessary. In 1972, a buffer zone of 4,600 acres around the existing 1,900-acre Plant (Industrial Area and buffer zone) was purchased to expand the open, undeveloped area providing additional protection. The buffer zone was essentially an open area, surrounded by a barbed wire fence, of the type used to fence grazing cattle from an area.

According to Ed Young, head of security operations at that time, the terrorist attack during the 1972 Olympics led the government to believe that trained terrorists could attack national defense facilities (Young, 8 May 1992). As a result, in 1978 plans were made to install a $5 million perimeter security zone surrounding the plutonium operations buildings. The perimeter security zone, when finished in 1983, consisted of a double-perimeter fence with closed-circuit television, alarms, and an uninterruptable power supply. Access to the area was controlled at three checkpoint guardhouses: Building 372 at the inner fence by Building 371; Building 762 by 707; and Building 792 by 771. Four guard towers, Buildings 375, 550, 761, and 901, were installed along the inner fence (Buffer, 1995). By 1985, a perimeter intrusion detection assessment system was in place, with its security centered in Building 764, to detect activities at the perimeter security zone (Thompson, 2 July 1993).

In 1983, a new policy required that all vehicles driven onto the Plant site be searched by security forces at the entrance gate. Guard posts and badge check houses were added at the west gate in 1985 and at the east gate in 1986. In 1988, material access areas were established to enhance security inside the production and classified building areas.

The first protests at the Plant brought out the guards in full force, with rifles and ammunition. During these protests, a booking area was established in Building 111 so that arrested protesters were processed on site instead of taking them to the Jefferson County facility. Protesters that crossed onto Plant property were put on a bus and transported on site. Many protesters were frightened by being brought inside the perimeter of the Plant, a response that surprised the security force. Over the years, some 1,500 arrests of protesters were made. As one of the Rocky Flats officials put it to the protesters, "We're equipped to deal with terrorists, but we are not equipped to deal with you people." Nevertheless, the arrests were peaceful and according to the head of security, Ed Young, no one was ever injured (Kennedy, 1994:27; Young, 8 May 1992). The practice of bringing protestors on site ceased due to infiltration concerns (Cunningham, 1998 interview). As protests continued and guards became accustomed to dealing with outsiders, the security forces were not fully armed or in full force.

Guardhouses were established in the west parking lot (133) in 1986 and at the west end of Central Avenue (113) in 1988. In 1990, the private security guard company, Wackenhut, took over the protective services contract.

The Plant protection organization had a security inspector force and a lock and key control group. The security inspectors regulated Plant and interplant access, provided security patrols and checks, and escorted Plant shipments. Lock and key personnel kept records of the locks and their keys, and of safes and their keys and combinations. Security maintained a weapons arsenal, conducted tours for potential contractors, trained new inspectors, investigated violations of Federal laws, and maintained liaison with local law enforcement agencies.

Strategically located cameras detected movement in unmanned, sensitive areas for increased security from unauthorized entry. Camera monitors were located in the nearest Plant protection guard post.

Procedures to heighten security measures were implemented in January 1991 because of the unrest in the Middle East. When the Persian Gulf War began on January 16, 1991, the Plant's emergency operations center was activated and staffed around-the-clock. The USDOE Rocky Flats Field Office provided the operational oversight of safeguards and security at the Plant. EG&G-Rocky Flats and Wackenhut Service, Inc., were the two primary contractors responsible for ensuring that protection program strategies, policies, and procedures were appropriately applied at the Plant to protect USDOE assets.

Document control was governed by USDOE regulations for the control and accountability of classified documents at Rocky Flats. It was responsible for the flow, safe keeping, and disposal of classified records, such as documents, microfilm, and correspondence.

The nuclear materials control group administered a computerized control system that accounted for all nuclear materials. It also supplied the USDOE nuclear materials information system with official material status information and data.

Communications

Communications at the Plant included a combination of commercial and secure telephone lines and teletype services, for secure and non-secure radio contact. Supplemental communication facilities included:

- Direct telephone links between the guard posts and central alarm station in Building 121;
- Direct telephone links between the central alarm station and ten key plant locations;
- Two push-button telephone call directors, one in the central alarm station, and one in the shift superintendent's office, with connections to thirty stations on and off the Plant site; and
- A public address system for general Plant or individual building announcements, national emergency alert and attack signals, building evacuation warnings. Direct connections to the nation's warning system and the metropolitan emergency telephone system.

There were two teletype services on site, one commercial and the other secure. The commercial teletype system, Western Union, based in Building 881, provided a printed copy of the message. The secure automatic communication network and a programmable terminal had a teletype center in Building 750. The secure automatic communication network, connected to USDOE headquarters in Maryland, could prepare, transmit, and receive classified and unclassified teletype messages from over forty USDOE offices and contractor locations. A newswire was introduced to the Plant site in 1971. This system, similar to an answering service, was updated each weekday morning and when events of major news would break.

There were twelve separate radio frequencies for two-way communication by departments on site. Radio communication was used by Plant protection, the fire department, Plant Services, the Plant postal service, radiation monitoring, Plant maintenance, and facilities engineering.

Radio communications between the Plant and other sites was also used. There was a two-way connection between the Plant and the Jefferson County Sheriff's Department, St. Anthony's Hospital, and nationwide USDOE locations and personnel over the emergency radio system. There was a listening watch for Colorado State Patrol transmissions.

Fire Safety

A twenty-five-person fire department provided immediate around-the-clock response to reports of fires and other emergencies. The fire department routinely inspected all Plant facilities for fire hazards; held fire training programs for its own members, as well as for members of building fire brigades and Plant protection personnel; and presented indoctrination courses for employees on fire prevention and reporting.

Fire brigades in the major buildings were trained to act as firefighters until the fire department personnel arrived on the scene. Plant protection back-up teams were trained to assist, where necessary. Security and fire personnel were cross-trained in the event additional backup was needed. Security could help with the hoses and the dress out into protective equipment. Fire brigade personnel were next in line to be given firearms, if necessary, in a security emergency (Cunningham, 1998 interview).

Plutonium is pyrophoric, and small particles will spontaneously ignite in the presence of oxygen. Special precautions had to be developed to prevent and to fight plutonium fires. Initially, the fire danger of plutonium was not completely understood, and preventative measures were phased in over time as the dangers became better known. These precautions to prevent and control fires eventually consisted of using glove boxes provided with argon or nitrogen atmosphere, displacing oxygen with carbon dioxide, and using heat-sensing and smoke-sensing devices and fire doors.

Two major plutonium fires occurred at the Rocky Flats Plant, the first in 1957 and the second in 1969. Buildings were modified and new safety procedures implemented as a direct result of these fires. The 1957 fire damaged Building 771, causing radiological contamination of much of the interior of the building. The fire spread from a glove box window on the fabrication line to the glove box exhaust filters, and the main filter plenum. The main fire was under control within 30 minutes of its discovery, but rekindled several times. Shortly after the fire was thought to be under control, flammable vapors collecting in the main exhaust duct exploded, spreading plutonium contamination throughout much of the building. Security officers discovered flames at around 10:10 p.m.; the fire was declared out by 2:00 a.m. the following day (September 12).

Prior to the 1957 fire, water was prohibited in the plutonium areas because of its moderating effect, potentially allowing a criticality event (spontaneous fission chain reaction) to occur. During the 1957 fire, water was used to extinguish burning combustible materials possibly contaminated with plutonium (i.e. Plexiglas and ducting materials in the exhaust plenum) without a criticality event or fatal consequences. As a result, standpipes and sprinkler systems were installed in plutonium handling areas throughout the Plant. Another result of this fire, which was propagated by combustible and flammable material, was that less flammable materials were investigated for use in glove box construction, specifically, a replacement for Plexiglas windows.

Off site release of plutonium into the atmosphere from the 1957 fire was estimated at approximately one gram. No major injuries were reported as a result of the fire. After that fire, many of the plutonium operations were moved to Building 776/777. The fire debris was cleaned up by 1958. For a more detailed discussion of the 1957 fire, see HAER No. CO-83-N.

The second plutonium caused fire occurred on May 11, 1969, in Building 776/777 glove boxes. The first notice of the fire came at 2:29 p.m., when an alarm, triggered by a glove box overheat system, alerted firemen. No one was injured in the blaze, but some thirty-three employees were treated for contamination. The fire occurred from spontaneous ignition of a briquette of scrap plutonium alloy metal contained in a small metal can, probably without a lid. The 1969 fire was the first time that water was used directly on burning plutonium (Note that in the 1957 fire, water was used to put out burning combustibles, not burning plutonium). The fire resulted in $26.5 million in property loss. There was an estimated plutonium release from the building of 0.000012 grams, all contained on the Plant site. Decontamination of the area took approximately two years. For a more detailed discussion of the 1969 fire, see HAER No. CO-83-O.

The fire changed the way that business was conducted at Rocky Flats and in the Atomic Energy Commission complex, and possibly had international influences. Prior to the fire, there was little quality control. After the fire, the complex started applying multi-layers of safety reviews and quality control (Calkins, 1998 interview). Safety features instituted after the fire included the creation of an inert atmosphere in the glove boxes to prevent propagation of fires and the addition of water sprinklers and more fire walls. Because of their efforts, fire department personnel received a Group Presidential Citation for heroism in the 1969 fire for risking their own health and well being to prevent a breach of the building, thus preventing plutonium contamination in the atmosphere.

<u>Health and Safety</u>

Background/History

During initial production and experimentation, little was known about the properties of uranium, plutonium, and beryllium, associated health risks, and allowable levels of exposure. Although specifics were not known, from the beginning of operations, it was recognized that health risks were associated with handling these materials: safety was always a priority within the weapons complex. Throughout the development of Rocky Flats, a great deal of expense and effort was dedicated to reducing identified health risks to both the workers and the environment. Public sentiment against the use of nuclear power, environmental concerns, economic factors, and issues raised by various protest groups helped keep the issue of health and safety a top priority at the Plant.

Plutonium is a radioactive material, emitting alpha and beta particles and gamma rays. Alpha particles are usually completely absorbed by a person's outer layer of dead skin, so are not harmful to the body. Alpha particles are harmful if ingested or inhaled, delivering a radiation dose to the lungs, liver, and bones that may increase the risk of cancer (Sutcliffe, 1995:2). Beta particles are more penetrating than alpha particles, but are less damaging over distances. Beta particles can be reduced or stopped by a layer of clothing. Gamma rays can easily pass completely through the human body or be absorbed by tissue, becoming a radiation hazard for the entire body. As a result, plutonium machining is performed under controlled conditions inside gloveboxes that include containment, filtering, and shielding (*Citizen's Guide,* 1992:16).

Most beryllium compounds are toxic; if inhaled they can cause a disease characterized as beryllium disease or berylliosis. Inhalation is the primary mode of beryllium entry into the body, and clinical symptoms may be either acute or chronic.

The health effects of enriched and depleted uranium are significantly less than the health effects of plutonium, and therefore can be handled outside gloveboxes with the airborne radiation contamination controlled through building or room ventilation. The principal concern when working with depleted uranium is uranium's chemical toxicity and beta particles. If taken into the body via inhalation or ingestion, uranium may damage vital organs such as the kidneys or lungs. Protective clothing was worn in uranium operation areas (Weaver, 1998 interview).

When the first quantity of plutonium was made in the 1940s, half of it was turned over to health and safety experts to study the impacts of this new material on people. Allowable exposure limits for personnel existed throughout the life of Rocky Flats, changing over time as new information and data was learned. Major improvements and technological advancements occurred in the areas of radiation protection, detection, bioassay, and dosimetry in Building 123. During the production years, funding for equipment and research programs appeared limitless (Trice, 1997 interview). Monies granted for health and safety issues allowed the labs access to state-of-the-art equipment to develop methods to do things faster, cheaper, better, and safer. Although production information was on a need-to-know basis, information, such as an injury or accident, traveled through the Plant like a wild fire (Cunningham, 1998 interview).

In 1963, the first patent granted for a Rocky Flats invention was assigned to John R. Mann, health physicist, and Art Wainwright, a former Plant employee. The patent was for an automatic radiation hand counter. Also in the 1960s, the SX-139 supplied breathing air garment was developed at Rocky Flats and approved by USDOE. This apparatus represented a two and one half-year effort to improve the supplied breathing air garments used at the Plant. In April 1995, John Schierloch, a mechanical engineer at Rocky Flats received a patent for a gas generation test canister prototype that measured the buildup of hydrogen inside plutonium residue storage drums.

In addition to the research efforts, accidents that occurred at the Plant spurred a number of new safety measures. The 1969 fire in the Building 776/777 glove boxes resulted in the creation of inert nitrogen atmosphere in the glove boxes and the addition of water sprinklers and more fire walls. As health regulations became stricter and more research on the effects of radiation or inhalation of particles became known, other changes took place at the Plant. In 1966, a personnel decontamination room was added to the southeast corner of the medical building (122), consisting of shower facilities and first-aid equipment. This addition enabled contaminated workers needing medical attention to go directly to the decontamination area rather than through the regular emergency building entrance (Buffer, 1995).

After decades of studies of the health effects to workers and the public living close to the Plant, the results have been inconclusive. One study, conducted on white males employed at Rocky Flats for at least two years between 1956 and 1980, recorded the cancer deaths in this group. Workers with higher internal plutonium concentrations were found to have higher rates of death from all causes (combining cancer and non-cancer deaths) and also found to have higher rates of certain types of cancer (lymphopoietic nemoplasms, digestive system, and prostatic). Workers with higher cumulative external radiation doses had higher rates of certain types of cancer (brain tumors, liver, lymphosarcoma, reticulum cell carcinoma, and myeloid leukemia). The results from both comparisons suggested a possible relation between exposure and observed health effects but were not conclusive (Wilkinson, 1987).

A limited study, conducted in 1990, of chromosome abnormalities in 18 plutonium workers at Rocky Flats was conducted. More chromosome aberrations were recorded in workers with higher cumulative radiation doses. No chromosomal differences were noted in workers from exposures to chemicals.

A 1981 study examined the relation between cancer rates and exposures to plutonium. The study found increases in many cancer types for persons in exposed areas (near the

Plant), as compared with those for unexposed areas. This study was replicated in 1987, and although the findings were confirmed, conclusions could not be drawn about an association between plutonium concentrations in the soil outside the Plant and cancer rates. No increase was found in cancer rates for all cancers combined, for radiation-sensitive cancers, or for cancers of the respiratory system in the region within ten miles of the Plant for both study periods.

In 1982, researchers measured plutonium concentrations in autopsy samples from more than 500 persons who died in Colorado. They compared those who lived near the Plant with those who lived far from the plant, and found a weak relation between plutonium concentrations in autopsy samples and distance from the Plant. However, the researchers concluded that the evidence was not strong enough to link the elevated concentrations to emissions from the Plant.

Researchers at the National Cancer Institute completed a study in 1990 of cancer incidence and mortality around 62 nuclear facilities in the United States. This study compared cancer rates in counties near nuclear facilities including the Rocky Flats Plant with those for counties farther away. The results from this study show slight elevations for some cancers in some age groups, but these data are hard to interpret because of limited information about other cancer-related factors.

Colorado Department of Health and the Environment began historical public exposure studies in 1990 to identify the potential health effects of past chemical and radionuclide releases from Rocky Flats to surrounding communities. Preliminary conclusions published in 1993 stated that past public exposures to contaminants from the Plant were minimal. Final results, due to be published in September of 1999, draw similar conclusions (Colorado Department of Health and Environment).

Epidemiologic studies conducted by the Colorado Department of Health and Environment suggest elevated cancer risks for Plant workers, but these results are not definitive. Scientists require fairly stringent evidence for such conclusions. Cancer rates must be high enough to satisfy criteria for statistical analysis, and must be clearly related to exposure to radiation or other hazardous substances that came from the nuclear facility. Epidemiologic studies of persons who lived near the Rocky Flats Plant have yielded conflicting results, mainly because data on exposures to radiation and toxic materials from the Plant were not sufficient and/or other cancer-related factors (i.e. smoking, etc.) were not considered.

The Rocky Flats Beryllium Health Surveillance Program, initiated in June 1991, was designed to provide medical surveillance for current and former employees exposed to beryllium. The surveillance program identified 27 cases of chronic beryllium disease and another 74 cases of beryllium sensitization out of 4,268 individuals tested. Beryllium disease affects the lungs of its victims, causing fatigue, shortness of breath, and persistent coughing.

Safety Programs

The first major safety program at the Plant was organized by General Manager, F.H. Langell in 1951. The first division physician came on site in 1952 and acted as the construction workers' physician (Buffer, 1995). By September 17, 1959 Rocky Flats had established a safety record of 7 million man-hours of work without a disabling injury. The safety figure eclipsed all performances by Colorado industry in addition to the fifteen other Dow plants (operating at the time) and the eight major facilities comprising the Albuquerque, New Mexico operations of the Atomic Energy Commission. In June 22, 1960, Dr. Leland Doan, President of the Dow Chemical Company, visited the site and presented a bronze plaque representing the President's Safety Award in recognition of the excellent safety record at Rocky Flats.

In 1966, dosimeter badges used to monitor employees' exposure to radiation were a Type-A gamma ray film badge. By 1969, all gamma ray dosimeters were converted to thermoluminescent dosimeters. Dosimeter badges were provided to all employees frequently in production areas. By 1976, all neutron badges used were thermoluminescent dosimeter badges. Rocky Flats was the first nuclear weapons facilities to use the thermoluminescent dosimeter badges. Exposure levels were monitored in the Analytical Health Physics Laboratory (Building 123).

Mandatory measurements for both external and internal doses were taken. Initially, detection limits for plutonium, americium, and uranium in urine samples was 0.15 disintegration per minute; by 1995, the detection limit was 0.02 disintegration per minute. This was due to improvements in procedures and equipment developed in the laboratory over the years.

Filtering of airborne radioactive particles was done through the use of individual respirators. A respirator fitting program was established in 1964, and in 1971 employees working in production areas were required to be clean-shaven so that the respirators would have a snug fit (Buffer, 1995:1971). In 1972, a system was established for checking the respirators for efficiency in the environmental test chamber of Building 123.

On January 1, 1973, a new safety program was kicked off. The "Life is Fragile – Handle with Care" safety program, designed to increase safety awareness in employees' homes and communities, was put together by and for employees. In 1973, the Atomic Energy

Commission allowed state health officials to have access to the fenced, secured areas of the Plant to check on general safety conditions.

In 1974, more direct emphasis was placed on research activity with the formation of health sciences, charged with the various aspects of radiation monitoring and employee health; and environmental sciences and waste control, overseeing all waste control activity and environmental monitoring. Radiation monitoring conducted in the analytical physics laboratory (Building 123) included gamma counting, tritium analysis, beryllium analysis, alpha and beta counting and the dosimetry process.

On July 1, 1991 the beryllium health surveillance program officially began. Employees found to be sensitized to beryllium were further evaluated for chronic beryllium disease (Buffer, 1995). Two medical studies were begun to monitor the long-term effects of exposure to beryllium and radioactive materials such as plutonium, enriched uranium, americium, and others. These studies, mandated by federal law (the National Defense Act of 1993), involve all former Plant workers, and are currently being used to detect early signs of disease.

In late February 1994, the Plutonium Working Group Report on "Environmental, Safety and Health Vulnerabilities Associated with the Department's Plutonium Storage," a 28-volume, 8,300-page report, was officially released. The report looked at plutonium environmental, safety, and health vulnerability issues at USDOE facilities complex wide. The report listed Rocky Flats as having five of the fourteen most vulnerable facilities - Building 771 (No. 1); Building 776 (No. 2); Building 779 (No. 7); Building 707 (No. 8); and Building 371 (No. 9).

New technology to detect small amounts of americium, a decay tracer product of plutonium, in employees' lungs was brought on line at Rocky Flats in June 1995. This technology was the most advanced in the industry and allowed direct measurement of radiation to be taken for a lung count. Two of the three rooms used by internal dosimetry used the new technology.

Health and Safety buildings considered primary contributors to the significance of Rocky Flats according to National Register of Historic Places guidelines include: Building 122 (emergency medical services); 123 (health physics laboratory); 442 (laundry for uranium-contaminated clothing); 778 (laundry for plutonium-contaminated clothing); and 886 (nuclear safety facility and critical mass laboratory).

Health Facilities

The original health facilities were located in the medical building (Building 122 – HAER No. C0-83-S) and the health physics building (Building 123 – HAER No. CO-83-B). A laboratory and administrative area were housed in the health physics building. Equipment used in collecting air samples, control and accountability of radioactive sources, recording limits of surface contamination and radiation exposure, personal protection, surveillance equipment, x-ray equipment, and a nuclear alarm system were also housed in Building 123. Personnel also monitored Plant employees for lung and systemic burdens, using body counting and radiochemical techniques. Analysis of personnel dosimeters and all airborne sample analyses, including stack samples and general room air samples, were conducted in the health physics laboratories.

The medical building (122) housed the doctor and emergency health care facilities. The medical department provided medical services to employees brought to them by the emergency unit of the fire department for diagnosis, first aid, x-ray, and minor surgical treatment, and also provided ambulance service (including helicopter transportation) to several local hospitals. The medical department performed scheduled physical examinations of all employees. A personnel decontamination room containing shower facilities and first aid equipment was added to Building 122 in 1966. This addition enabled contaminated workers needing medical attention to go directly to the decontamination area rather than through the regular emergency building entrance (Buffer, 1995).

Nuclear Safety Department

The nuclear safety group was established in 1953. The primary purposes of the nuclear safety department were to generate technical criticality safety information, review operating procedures for nuclear safety, provide guidance for implementing those procedures, and establish nuclear safety policies for the safety of production operations. Nuclear criticality safety can be defined as practices associated with avoiding an accidental nuclear criticality event or spontaneous nuclear fission chain reaction. In a nuclear chain reaction, a neutron splits one uranium or plutonium atom into two smaller atoms, which in turn release energy and neutrons; these neutrons split other fissile atoms, releasing more energy and neutrons. Eventually enough atoms are split and neutrons released that the reaction sustains itself. The chain reaction produces energy that can be converted to electricity or used in atomic weapons. A criticality event would not result in a nuclear explosion, but could liberate a large amount of energy and high levels of radiation. The presence of large quantities of fissile materials in numerous forms on the Rocky Flats site made it necessary to maintain an active criticality safety program. Although a number of nuclear criticality accidents have occurred nationwide, the Rocky Flats Plant had none.

The nuclear safety department was divided into two groups: the criticality mass laboratory, where experiments were conducted, and criticality engineering. The principal functions of criticality engineering included writing criticality limits and procedures for the safe handling of fissile materials, implementing the limits and procedures in all areas that handled fissile materials, training and indoctrinating personnel who handled fissile materials, and performing auditing operations for compliance with USDOE guidelines. Criticality limits, the amount of material allowed in any one place (process line, storage container, etc.) at one time, were strictly enforced. If criticality limits were exceeded, penalties were severe, possibly resulting in termination (Rothe, 1997 interview).

Criticality tests were conducted in the criticality mass laboratory after 1964. Until the early 1960s, criticality testing was done after-hours in the production glove boxes. Experiments were only allowed to go towards criticality, but not allowed to go critical. Values were then extrapolated. The need to obtain more actual values was recognized and in 1964, ground was broken on a state-of-the-art criticality mass laboratory (Rothe, 1997 interview). Investigators would set up the production materials in various arrays to perform neutron- multiplication experiments and make predictions with respect to safe geometries for various kinds of production vessels, spacing parameters, shipping containers, and other items. These *in situ* experiments conducted outside Building 886 were always subcritical; neutron count rates were observed as criticality was approached but never reached.

Experiments at Rocky Flats validating the safety parameters for the storage of fissionable solutions in raschig ring tanks resulted in the design of two substitute storage tank configurations: the annular tank and the poison tube tank. These designs allowed for more economical solution testing with no decrease in safety. The poison tube tanks were not used at the Rocky Flats Plant due to the change in the overall site mission; however, they were used at other USDOE facilities. Experiments were also conducted to validate the cross-sections and usefulness of materials used at the Rocky Flats Plant.

Critical Mass Laboratory (Building 886) (HAER CO-83-A)

To further reduce hazards, criticality tests were moved to a dedicated facility, Building 886. The principal function of the laboratory was to provide accurate criticality data for engineers to use in establishing safe nuclear procedures. The laboratory facility had approximately 12,000 square feet of space for electronics, fissile material storage, and critical mass testing. The actual tests were conducted in a room having 4'-thick concrete walls and a 2'-thick concrete ceiling. The room was leak tested to insure that, in the event of an accident, no contamination would be released to the environment. The room was sealed during experiments. Redundant automatic shutdown mechanisms were built into each experimental system to preclude a nuclear incident. All experiments followed detailed written procedures and were conducted by trained personnel. The criticality safety group at Rocky Flats performed experiments and calculations to identify container or vessel geometries or arrays of nuclear material that had the potential to spontaneously fission. Experiments and calculations were conducted to evaluate the potential for criticality under varying conditions and to validate computer programs used for criticality safety analysis.

The first experiments in the building were conducted in 1965 with highly enriched uranium. Between 1965 and 1992, approximately 1,600 critical mass experiments were conducted on enriched uranium metal and solution, plutonium metal, low enriched uranium oxide, and several special applications. Additional testing programs were instituted after 1969 when the critical mass program at Lawrence Radiation Laboratories was shut down and transferred to Rocky Flats (Rothe, 1997 interview).

After 1983, experiments were conducted primarily with uranyl nitrate solutions, and did not involve solid materials. Experiments continued until 1987, when testing programs were temporarily stopped for routine equipment modifications, contamination control, and ventilation repairs. Before needed corrections and modifications were completed in 1989, operations at the entire Rocky Flats Plant were curtailed due to the FBI raid. Criticality research at the criticality mass laboratory never resumed.

Heating, Ventilation, and Air Conditioning Systems

Contaminant Zones/Filtration

Heating, ventilation, and air conditioning systems confined hazardous materials within process areas to prevent the dispersion of radioactive aerosols, noxious fumes, and vapors into areas normally occupied by personnel (Drawing 16). They also controlled the release of such contaminants from a production facility to the lowest practicable levels, both under normal operating conditions and under accident conditions. Heating, ventilation, and air conditioning systems included not only air ventilation capability but also, in many buildings having nuclear materials, inert gas ventilation that provided environmental control and fire protection for specific areas.

For confining radioactive materials, individual buildings were divided into several zones (Zones I-IV), separated by physical barriers. The ventilation pressure was increasingly negative from zone to zone toward areas of potentially higher radioactivity. Ventilation atmosphere flowed from areas having the least potential for radioactive contamination toward areas having progressively higher potentials. Definite pressure differentials were maintained between the zones.

Zone I, the primary confinement zone, included glove boxes, canyons, vaults, and their exhaust atmosphere handling and cleaning systems (i.e., areas of highest potential radioactive contamination). There was either one additional, less critical zone between a Zone I area and the final containment barrier to the outside environment, or a monolithic concrete floor, wall, or roof with no penetrations to the outside environment. Zone I atmosphere was negative with respect to the atmosphere in all other zones.

Zone IA (buffer zone) included access air locks to glove boxes and canyons, downdraft table enclosures, downdraft tables, hood enclosures, tank vaults, and their exhaust atmosphere handling and cleaning systems. Zone IA areas were essentially open containment areas (hoods, and downdraft tables) where the capture velocity of the ventilation atmosphere was utilized and controlled rather than a fixed pressure differential maintained.

Zone II (secondary confinement) included the process rooms and work areas containing the Zone I and Zone IA confinement areas, enclosures, and systems. Zone II atmospheres were maintained at a pressure less than that of Zone III.

Zone III (tertiary confinement) included access areas, individual process control rooms, decontamination areas, and the corridors surrounding Zone II and adjacent to the outside shell of the building itself. Zone III also housed the air supply and return system and utility systems that potentially could contain slight radioactivity. The pressure in Zone III was negative relative to that in Zone IV of the building.

Zone IV space included such areas as heating, ventilation, and air conditioning control rooms and general non-radioactive utility and support areas. Zone IV pressure was slightly negative relative to outside ambient air pressure.

The air pressure balance between zones was maintained by differential pressure-sensing instruments and was controlled by inlet and outlet zone dampers. The pressure differentials maintained air flow toward Zone I areas, then to final filtration, prior to being exhausted to the outside atmosphere.

The outside shell of the building provided the final containment barrier for radioactive materials. There were no openings in those portions of the building shell that separated Zone I, IA, and II areas from the outdoors. Passage from Zone III through the building outer shell to the outdoors was through air locks.

High Efficiency Particulate Air Filter Testing Laboratory (Building 442) (HAER No. C0-83-AG)

Air exhausted from facilities handling beryllium, plutonium, and uranium was exhausted through several stages of high efficiency particulate air filters. The high efficiency particulate air filters were purchased from various manufactures and tested by the filter testing group prior to use. Each plutonium production building was fitted with at least two banks of high efficiency particulate air filters. The filter testing group was formed in 1979 to act as an independent group to test the quality of high efficiency particulate air filters (ChemRisk, 1992:95).

Operations in the high efficiency particulate air filter test facility were considered critical. Production buildings were continuously monitored for radioactive contamination. Air exhausted from the stacks of process and research buildings was monitored to detect releases of particulate radioactivity and toxic dusts and chemicals. Also, ambient air was monitored for airborne particulate matter, both on and off the Plant site.

Construction of the original section of Building 442, which housed the filter laboratory was completed in 1953. The original building, containing 2,480 square feet, is a one story, reinforced concrete structure. The newer part of the facility (constructed in 1975) is a pre-engineered metal building. This addition housed the warehousing operation.

Breathing Air System

Clean, dry, breathing-quality air was available for personnel who were required to wear protective suits or masks to perform operations where the atmosphere had less than 19.5 percent oxygen, was radioactive, highly toxic or noxious, or could be hazardous. Air was supplied in personal tanks or canisters. Typical of these kinds of operations where supplied air was used include cleaning liquid storage tanks, changing contaminated filters, spraying a toxic paint or coating, or entering a smoke-filled room to extinguish a fire. Workers in plutonium process buildings were the most frequent users of supplied breathing air.

The most extensive breathing air system was in the 700-area buildings. Either one of two compressors in Building 708 could supply breathing air to Buildings 707, 771, 774, 776, 777, and 779. Portable compressors also provided Buildings 333, 444, 559, and 881 with breathing air capability.

Inert Gases

An inert atmosphere (nitrogen and less than 5 percent oxygen) was used in various glove boxes and storage areas to minimize the possibility of fire. Total nitrogen consumption during fiscal year 1975 was 515.6 million cubic feet; in 1976, nitrogen consumption was at the rate of 58,000 to 60,000 standard cubic feet per hour.

Gases used in the inert atmosphere were normally supplied from an on site, liquid nitrogen production plant that was owned and operated by a commercial supplier. A secondary supply was a liquid nitrogen storage facility that received liquid nitrogen from the on site plant or by truck or rail shipment from an off site commercial supplier. Distribution of the nitrogen began at Building 223 with an underground, closed-loop distribution line. From there, the gas was sent to Buildings 371, 701, 707, 771, and 776. The nitrogen could be delivered in either clockwise or counterclockwise directions, should one side of the loop have become inoperable. An interior system delivered the gas from the 776 to the 777 area in Building 776/777.

Another inert gas system was a manually controlled argon system used in several plutonium fabrication, assembly, and research buildings. It consisted of a supply tank with distribution headers to various stations. It was used as a shield in arc welding and to provide an inert glove box atmosphere.

Nitrogen and argon gases were used as conveying mediums for solid samples in the close-carrier transfer systems of Building 371. Argon was also used in Building 371 to safely indicate leaks in calcium metal storage facilities; was mixed with fluorine, as make-up in a fluorination process; used to provide an inert atmosphere for molten plutonium metal that was being purified; and used as a purging agent.

Health and Safety Practices

With the exception of those employees working in low-contamination areas such as the laboratories, all the men (women initially were not allowed to work in the production buildings) wore white clothing - coats, pants, hats, underwear, socks, and booties - provided by the Atomic Energy Commission/USDOE (B. Richardson, 1995). Depending on the area and task involved, at least 20 percent of an employee's time (1.5 hours per day for each 8-hour shift) was dedicated to issues and practices relating to safety. At a minimum, each employee changed out of their protective clothing for morning, lunch, personal, and afternoon breaks. After each break, the process was reversed (L. Wilson, 1998 interview). In addition to the time required for clothes changing, individuals were routinely monitored with hand scanners and other mechanical devices. This protective clothing was laundered in various buildings; originally, Buildings 771, 881, and 991 had their own laundries, and Building 442 laundered the clothing from Building 444. When Building 778 was constructed, the laundry for the plutonium-related buildings was washed there; after 1976 -- when Building 442 became the filter test facility -- all laundry on the site was handled in Building 778 (ChemRisk, 1992:96).

Plutonium

Preventing employee contamination and exposure was the number one priority at the Rocky Flats Plant. Many of the systems developed to protect Plant employees and area residents were exclusive to the Rocky Flats Plant; they were not needed in other manufacturing plants. Glove boxes and stainless steel enclosures were designed for plutonium handling. Rubber gloves, usually impregnated with lead oxide, were affixed to the glove boxes to facilitate the handling of plutonium. The glove boxes also had lead-glass windows and 0.125"-thick lead shielding to protect personnel against gamma rays and x-rays. Water walls and hydrogenous materials were used where neutron shielding was required.

Containment and shielding meant that plutonium was machined inside lead- and water-lined glove boxes. Plutonium was moved from workstation to workstation within the six modules in Building 707 in a system of interconnected enclosed glove boxes and lines that ran for several hundred feet. In addition, Building 707 was connected to Building 776 via a glove box conveyor line (B. Richardson, 1995). In 1971, the operations in the waste treatment building (774) were enclosed, providing containment of radioactive airborne particles. Additional shielding, using lead, leaded glass, and Benelux and Plexiglas was added to the glove boxes and conveyor lines in Buildings 776/777 and 771 in 1968 to reduce exposure to radiation (EG&G, 1994). From the outset of operations in the late 1950s, employees wore dosimetry badges to measure external radiation exposure, and radiation and health physics monitors watched operations in the production buildings (Buffer, 1995).

Certain glove boxes had inert nitrogen atmospheres containing a maximum of about 5 percent oxygen to protect against fire propagation. Additional protection was provided via the use of heat- and smoke-sensing devices, roll-down fire doors, and fire doors with fusible links within the glove box system, and quick-connect fire extinguishers.

Plutonium ingots and parts were generally stored in closed containers within a large vaults. An inert atmosphere was maintained inside some vaults. One inerted vault had 10"-thick concrete walls with 7.25"-thick windows made of laminated glass enclosing gelled water. Material was introduced and removed from the vault by means of a computer-operated retriever able to be manipulated in three different directions.

Safety in the plutonium fabrication and assembly operation was assured by the following physical and administrative features:

- The operations were enclosed within steel glove boxes, and operating personnel wore protective clothing;
- Certain steps were performed in an inert atmosphere to reduce the chance for combustion;
- Contaminants were filtered from liquid coolants and inert atmospheres;
- Heat, radioactivity, and oxygen levels were continuously monitored;
- Equipment was shielded to protect personnel from exposure to gamma, x-ray, and neutron radiation;
- Fire doors confined fire, and there were effective fire-suppression systems in place;
- Plutonium was handled remotely, whenever possible;
- Criticality limits were posted for easy reference;
- Safety inspectors maintained a constant vigil for unsafe conditions and practices; and
- There was adequate indoctrination and on-the-job training of personnel.

Beryllium

Protective measures against dust containing beryllium particles required proper ventilation that included the use of specialized exhaust hoods, immediate availability of respiratory equipment, performance of certain operations under wet conditions, and continuous monitoring at all workstations. Employees in beryllium areas wore protective clothing and had to wash themselves before eating, drinking, or smoking, and prior to leaving the area.

Uranium

Workers in uranium fabrication areas wore protective clothing; before leaving their workstations and before eating, drinking, or smoking, they were required to wash adequately.

Non-Radioactive Materials

Regulations for the safe use, storage, shipment, and disposal of various chemicals and materials at the Plant were found in such publications as the material hazards manual, the chemical safety data sheets of the Manufacturing Chemists' Association, the health safety and environmental manual, operational safety analyses, and individual building rules. In its list, the material hazards volume records such information as composition, ignition temperature, irritants, odor threshold, toxicity, reactions with other materials, flash point, flammable limits, and human tolerance limits. In addition, audits, inventories, and reviews were frequently conducted at the Plant.

<u>Research and Development</u>

Research Efforts - Production Processes

In the early years, the Los Alamos (New Mexico) and Lawrence Livermore Laboratory handled most of the research efforts. Any research done at the Rocky Flats Plant was incorporated into production engineering for new weapon design. The Rocky Flats Plant specialized in research concerning the properties of plutonium. Since very few locations in the United States had the capabilities to work with plutonium, discoveries regarding its behavior and properties were largely unknown. Plant personnel conducted research on the properties of many materials that were not widely used elsewhere. They also developed new materials and processes, applying their new knowledge as they went. Plant personnel considered projects associated with research and development exciting (Stakebake, 1998 interview). Although the mission of the Plant changed to waste management in the early 1990s, research and development programs continued at full scale. Laboratories were established in each of the three manufacturing buildings, specializing in the materials of the Plant, either plutonium, enriched uranium, or depleted uranium.

Each production process in a given building had a number of research and development personnel, technicians, and radiation monitors to handle problems as they arose. During Rockwell's contract, there were over 300 people involved in research and development (Brown, 1998 interview). Research efforts were chiefly directed toward improving the methods by which plutonium parts were produced for nuclear weapons. When the Rocky

Flats Plant became the sole producer of plutonium triggers in the 1960s, research and development activities increased markedly.

Research issues related to metallurgy, machining, joining, material evaluation, inspection, nondestructive testing, coating, remote engineering, and chemistry were carried out in the 300, 400, 700, 800, and 900 areas of the Plant.

Specific research labs included: Building 779 (plutonium research); Building 865 (non-plutonium metals and the development of alloys); Building 993 (bonding tests on stainless steel and uranium alloy); and Building 886 (critical mass experiments with uranium and plutonium). Building 886 was one of two remaining general purpose critical mass laboratories in the United States. Experiments conducted at Building 886 were used to set safety standards for the Nuclear Regulatory Commission (ChemRisk, 1992: 85-92; EG&G, 1992).

Additional testing laboratories were constructed as needed. Building 125 (standards laboratory) was used for analyses of incoming materials for quality assurance/quality control. Building 126 (calibration laboratory) was used to calibrate the machining equipment used in manufacturing precision components. Building 705 was used to test coatings used on materials, and develop work for reactor fuels using depleted uranium oxides and beryllium. Design waste treatment processes were tested in Building 701. Building 559 was used for analysis of the purity of plutonium. Building 561 expanded the capabilities of the laboratories in Building 559. Under the research and development theme, buildings considered primary contributing elements to the historic significance of Rocky Flats included buildings: 125 (testing-standards lab); 126 (testing-calibration lab); 559 (lab - chemical analytical support for plutonium production); 705 (coating lab); 779 (lab - plutonium production and recovery); and 865 (enriched uranium-material processing).

Areas of Research

Material Handling

The metallurgy section at the Plant studied the properties of plutonium and its alloys under the conditions that existed as the metals were shaped by various metalworking methods. Other metals such as beryllium, titanium, depleted uranium, stainless steel, copper, and aluminum were subjected to melting, casting, forging, rolling, forming, heat treating, and property-measuring operations. Building 865 was built in 1970 to house metalworking equipment for the study of non-plutonium metals and the development of alloys.

Conventional methods for machining plutonium, uranium, beryllium, and other metals, were continually examined in support of production. Experts knowing the latest techniques worked at Rocky Flats. In many cases, there were no commercial substitutes available. Cutting edge technologies conducted at the Plant resulted in a number of patents, doctoral degrees for some of the personnel working on the technologies, and numerous scientific discoveries. Machine shops and machinists would fabricate whatever was needed to facilitate a project. Each production person had access to a number of research and development technicians in the building to handle problems as they arose.

The joining group worked to improve the technology of bonding. They performed resistance welds, welds with an electron beam pulsed arc, a gas metallic arc, and a gas tungsten arc, plus solid-state bonding, using a variety of dissimilar metals.

Research was conducted in inspection methods using laser interferometry, interference microscopy, advanced ultrasonics, and acoustic emissions were developed at the Plant. Nondestructive testing of stainless steel, beryllium, and other materials included ultrasonic, acoustic emission, and eddy current techniques. Optical methods for measuring surface roughness by light scattering and holography were also investigated.

Experimental coating and surface-finishing activities included:

- Electroplating with copper, nickel, chromium, silver, gold, and cadmium;
- Autocatalytic plating with nickel, gold, and copper;
- Chemical milling and polishing of metals;
- Anodizing aluminum and beryllium;
- Oxidizing steels; and
- Organically coating with polyvinyl chloride, Teflon, polyurethane, and epoxy.

Research efforts improved corrosion protection, manufacturing methods, and joining and bonding techniques.

Research associated with remote engineering focused on reducing personnel radiation exposure with the use of remote controls for various processes. New technologies used included:

- Mechanical arms, hydraulically operated to replace human arms in the americium line where extremity exposure was a hazard;
- Devices that could be used in glove box atmospheres to perform as human hands and arms would perform;

- Robots that could carry out repetitive operations and, guided by a human, could handle thermally hot or very heavy operations; and,
- A remote-control vehicle to change cobalt sources for nondestructive testing.

Chemical Research

All of the major production areas contained their own chemical laboratories. Depending on the material that was handled, a wide variety of research projects were conducted. Research at the Plant included:

- Preparing purified actinide compounds, such as oxides, nitrates, fluorides, chlorides, sulfates, and similar compounds;
- Making pure metals and alloys of metals;
- Custom casting foils, disks, and ingots for special orders from USDOE design agency laboratories;
- Selectively hydriding uranium and plutonium;
- Converting the oxides of uranium and plutonium to fluorides, separate from the production stream;
- Developing special separation and purification methods for materials containing plutonium, uranium-235 and -233, americium-241, neptunium, and curium;
- Improving techniques for the recovery of americium;
- Materials development, process instrumentation and control, and equipment design and development of on site waste treatment processes; and
- Development of chemical standards.

Studies also resulted in the development of instruments that were used in improving glove box gloves, bags, and windows; storage testing; and studying the incineration of low-level plutonium-contaminated wastes.

Waste Treatment

Research and development on the treatment and handling of waste was varied and on-going throughout the life of the Plant. Some the studies were oriented towards handling special materials, such as plutonium, while others addressed problems associated with disposing of wastes produced during the production processes.

Other projects included development of an incinerator used for burning plutonium-contaminated waste, development of a waste compactor and development of the ferrite waste treatment process. The plutonium incinerator, designed and built by Plant personnel, was installed in Building 771 in 1958. This equipment functioned like an industrial incinerator with a series of filters, scrubbers and heat exchangers designed to purify toxic gases and other byproducts of the burning process.

In July 1979, the two story, 3,000 square foot fluidized-bed incinerator, housed in Building 776/777, made its first continuous 108 hour run. It brought to a close nine years of research and development on the project. The $2 million incineration facility was designed to demonstrate a process for combustion and reduction of low-level transuranic wastes generated at the Plant.

On September 26, 1985, the waste treatment process called ferrite waste treatment, which significantly improved the method for removing actinide contamination from waste water, earned Rockwell the IR-100 Award (an industry-wide award).

On May 23, 1995, an innovative way to treat waste with waste, which was developed by researchers at the Plant, was unveiled to the public during demonstrations of polymer encapsulation conducted on site.

Explosive Bonding Pit

Explosive bonding experiments were conducted at the explosive forming area near Building 993. Many of the experiments were designed to bond together flat plates of stainless steel and uranium alloy. Experiments conducted in March of 1968 with 192 grams of 40 percent dynamite drove a stainless steel plate into radioactive material, forming a bonded laminate. Other experiments of unknown nature took place near Building 993 for at least two and one half years. Until March 1968, experiments took place inside buried, sand-filled, 55-gallon drums. The explosive events took place below grade. Air shocks from the explosions were objectionable to Building 991 occupants, so a pit was dug into a hillside near Building 993 to house the apparatus and mitigate air shocks. The 10' x 19' pit was approximately 4' deep.

Special Orders

The Plant conducted special order work for other facilities in the nuclear weapons complex, the Department of Defense, and to fulfill needs of other Federal departments and agencies. Most of the special order work at Rocky Flats did not involve materials outside those used in regular production activities. The tracer work was one of the few exceptions.

Radionuclide tracers were introduced into manufactured components and triggers destined for off site test shots. These materials were blended into the regular component materials so that scientists could study performance of the different weapon components based on post-test distribution of the rare tracers. After the test shot, the scientists could then core through the site and find out how each tracer reacted, enabling them to calculate how each of the components acted in the detonation. Neptunium tracers, associated with both uranium and plutonium components, were manufactured in Buildings 771 and 881.

Most of the special order work was relatively short-lived. Perhaps the biggest exception to this was the zero power plutonium reactor project, in which Rocky Flats manufactured approximately 4,000 stainless steel-clad fuel elements consisting of plutonium, molybdenum, and uranium. Production took place from 1967 to 1968. The Plant manufactured the fuel rods for installation in the reactor at Argonne National Laboratory. The zero power plutonium reactor fuel elements were made by first alloying uranium and molybdenum in Building 444. The uranium-molybdenum alloy was then sent to Building 771, where it was alloyed with plutonium by casting it into plates of various sizes. The ternary alloy plates were clad in stainless steel envelopes in Building 776/777 and sealed by welding.

From the mid 1970s through the late 1980s, the Plant was involved in a series of projects involving depleted uranium manufacturing expertise already developed at the Plant. One such project required the manufacturing of thousands of calorimeter plates used for shielding in reactors at Switzerland, Harvard University, and Brookhaven National Laboratory. The Army contracted the Plant to develop armor-piercing ammunition rounds. This project ran from the mid 1970s to the late 1970s. The Army, fearing that the armor-piercing technology may fall into the wrong hands, came back to the Plant in 1981 to develop bulletproof armor plates for the M1A1 tanks. For the Army projects, the Plant was only involved in prototype development of these products and not the full-scale production.

Rocky Flats was also involved in Project Plowshare, an effort to develop technology for using nuclear explosives for peaceful applications, such as excavation and uncovering of deep mineral deposits. Example applications envisioned for the technology included excavation of a sea-level alternative to the Panama Canal and west coast harbors for Africa, Australia, and South America. Rocky Flats' involvement in making components for Project Plowshare lasted from around 1959 to the mid-1970s.

Natural Sciences

In 1976, Colorado State University at Fort Collins, under a contract with the Energy Research and Development Administration began a two-year program to determine whether the approximately one hundred deer that roam on and off Rocky Flats ingest any plutonium and consequently transport (via ingestion/excretion) it to other locations, primarily the foothills. The university was already under contract with the Energy

Research and Development Administration to study plutonium in soil, vegetation, and small mammals at Rocky Flats. Results of the study indicated that none of the Plant or animal communities contained evidence of radioactive contamination. Follow up studies on the grasshoppers and mice in 1991 also failed to find any evidence of plutonium in the studied ecosystem.

In 1976, Rocky Flats was selected as a test and research center for small wind energy conversion systems and a wind energy research station was established in the northwest corner of the Plant. In October 1984, the wind energy research center at the wind site became part of USDOE's Solar Energy Research Institute organization.

Clean-up and Remediation Studies

In 1994, Rocky Flats was selected as one of fourteen federal technology demonstration sites by a USDOE advisory committee to develop on site innovative technologies. The site was a candidate for demonstrations of two of nine technologies identified by the committee - thermal desorption and microwave solidification. A news release issued February 9, 1996, announced that workers at Rocky Flats were using a low temperature process to treat contaminated soils from a former chemical disposal site. The low temperature thermal desorption process involves heating contaminated soils to temperatures from 150 to 300° Fahrenheit, which causes the organic chemicals in the soil to pass off as vapor. The vapors are then condensed into a liquid and passed through a granular-activated carbon unit. Wastes captured in the desorption process were treated on site and/or disposed of at an off site waste facility. In the early 1990s, Plant personnel developed a microwave melter to immobilize wastes in a vitreous, glass-like substance.

On August 25, 1994, representatives of Rocky Flats signed a collaborative agreement between EG&G Rocky Flats and the Los Alamos National Laboratory. The agreement provided for the development of unique technical approaches to environmental cleanup and restoration activities at Rocky Flats.

Support Facilities

An additional 379 structures at the Plant provided a variety of services, including offices, storage buildings, shops, utilities (heating, electrical, and water supply systems), waste management, offices, and maintenance over the years. Of those structures, seven are considered part of the Rocky Flats Plant historic district, including Buildings 333, 334, 374, 441, 443, 551, and 995.

Office Administration and Supplies

Two office buildings and a warehouse are considered part of the historic district, Building 111 (HAER No. CO-83-V), Building 441, and Building 551. Because Building 111 in the 1950s was the main check-in and access point for employees, it is considered part of the Plant security.

Building 441 contains offices and administrative support facilities. The building formerly supplied analytical and general laboratories required for various Plant A operations (depleted uranium, beryllium). Testing conducted in Building 441 included x-ray chemical analyses, spectroscopy, emission, general chemistry, and water analysis (Ed Vejota, 1998 interview). When the uranium operations were transferred to Oak Ridge, most of the labs were closed down in Building 441 between 1965-1968. After that time much of the structure was converted to office and administrative support facilities.

Building 551 was constructed in 1953 as a warehouse and fabrication shop for metal cleaning, welding, cutting, and threading. The structure is single story, concrete and concrete block L-shaped outline containing approximately 100,000 square feet. A small cluster of offices is located in the southern end. Various safety equipment (except safety glasses), spare parts, and orders for special equipment were taken in this area. Since its construction, Building 551 has been used as a primary warehouse (USDOE, 1989). Completed materials from Building 991 were shipped to Building 551 for staging and loading onto trains. Likewise, all equipment and materials were received in Building 551, temporarily stored and then shipped to the appropriate buildings. Shipping and receiving of nuclear parts to the building were discontinued when trucks replaced the train system (Rockwell, 1989).

Waste Management

Waste facilities at the Rocky Flats Plant consisted of treatment facilities, process lines, storage facilities, one disposal facility, and support facilities. The historic district waste treatment buildings included: 374 and 774 (Liquid Waste Operations) (HAER No. CO-83-AI); 776/777 (HAER No. CO-83-O) and 889 (Solid Waste Operations); and 995 (Sewage Treatment Plant).

Liquid Waste Treatment

Buildings 774 and 374 are responsible for treatment of liquid process wastes to remove chemical and radioactive constituents. Liquid process wastes were kept separate from sanitary wastes and treated in separate waste treatment facilities. Building 371 and 774 operations treated all liquid process wastes from Building 771 plutonium recovery processes, plus all other liquid process wastes that had too much plutonium content for on site impoundment. The treatment was for the purpose of liquid waste disposal; it included no plutonium recovery. Building 774 was the only Rocky Flats facility capable of processing high-level radioactive liquid waste. Building 374 processed liquid wastes contaminated with lower levels of radioactivity.

Building 774 received radioactive acid wastes, caustic, aqueous, and organic wastes, waste oils, non-radioactive waste, and photographic solutions. These wastes were either piped directly into Building 774, or transferred in drums, containers, or other types of packaging.

Treatment of liquid waste was divided into two stages. The first stage operation in Building 774 treated only the liquid materials associated with plutonium. Recovered materials were packaged in sludge drums. Aqueous wastes not compatible with the first stage operations were isolated and solidified with cement. The second stage operation in Building 774 handled all other Plant liquid process wastes that required treatment. It also provided further treatment for the first stage effluent. The second stage consisted of two precipitation processes, one continuous and the other batch. The continuous process was used for liquids that were only radioactively contaminated. The batch precipitation process was used for all liquids that were chemically, as well as radioactively contaminated. Both processes utilized the same chemical reagents that were used in the first stage. The precipitate formed was filtered and packaged in drums as sludge. The treated effluents from both processes were held in isolated tanks until analytical sample data was obtained. Treated wastes not meeting the radioactivity requirements were recycled through the appropriate second stage process.

Chemically contaminated process waste that met radioactivity standards without treatment was impounded in lined evaporation ponds; process liquid wastes that met required water specifications without treatment were impounded in Ponds A2 and B2. The chemically contaminated waste impounded in the asphalt-lined ponds was transferred to the evaporator feed tanks in Building 774 as capacity permitted. Recovered waste materials were dried, converted into salts, and boxed for storage.

Contaminated lathe coolant and organic solvent were transferred from their sources via separate pipelines into an isolated feed tank system in Building 774. Miscellaneous organic solvents and oils received in containers were filtered and transferred into the organic solvent feed tank system also. These wastes were processed to form a solid and packaged in drums.

In the 1970s, a series of changes were made in the 774 process. After the 1970s, radioactive processes were contained in glove boxes. In 1982, laundry water processing was shifted to Building 374. Low-level and transuranic waste continued to be processed in Building 774 until 1987, when the low-level processing was halted in anticipation of the startup of the fluidized-bed incinerator in Building 776/777. The transuranic waste processing operation was then redesigned.

The role of Building 774 in process waste treatment diminished with the inauguration of the new process waste treatment facility in Building 374. Building 774 continued to process all contaminated organic waste that could not be incinerated, but decontaminated only those process wastes from the old recovery process in Building 771. Decontaminated waste solutions were then transferred to Building 374 for evaporation.

Construction on Building 374 began in 1977 and was completed in 1980. The waste treatment facility is a freestanding structure approximately 140' X 145'. Total floor space is approximately 66,330 square feet. The evaporator began operating in 1977 to process high-nitrate wastes from the lined ponds.

Building 374 Waste Treatment Facility was designed to remove radioactive and chemical constituents from aqueous waste received from Buildings 122/123, 371, 443, 444, 460, 559, 707, 774, 776/777, 778, 779, 865, 881, 883, 889, and the 207-series solar ponds through the process waste collection system (valve vaults).

The new production wastewater treatment plant was designed to replace Building 774 as the primary-process wastewater treatment plant. Building 374 was designed to more effectively treat nitrate wastes, had a greater processing capacity, improved hazardous material containment systems, and improved control systems. All wastes received were treated for disposal by:

- Decontamination - precipitation;
- Neutralization;
- Evaporation;
- Vacuum filter; and/or
- Spray dryer/saltcrete.

The effluents from these processes were converted into reusable distilled water, disposable solid wastes (saltcrete and vacuum filter sludge), and exhaust gases.

Building 374 houses approximately thirty-three tanks for receiving and storing liquid process waste for treatment; treatment areas (including the evaporator, spray dryer/saltcrete, decontamination-precipitation, neutralizer, and the vacuum filter); container handling and storage areas; supporting mechanical equipment and utilities for the building; a chemical preparation area; and office areas. An enclosed shipping and receiving dock was located on the east side of the building for receiving miscellaneous aqueous wastes from sources not connected to the process waste collection piping system and for receiving empty containers and other process-related items. The dock was also used for shipping full containers of processed solid wastes.

Wastes received at the building were segregated according to radiation and chemical content in order to tailor the treatment process to specific waste parameters for more effective treatment, and to generate a uniform sludge. Treatable liquid waste streams first underwent radioactive waste treatment, which consisted of a combination of precipitation; acid neutralization; sludge filtration, drying and packaging; and process vent scrubbing. Precipitated solids were removed and solidified by cementing in drums. Filtrates were further processed to remove chemical contaminants. Desaltable liquid waste streams were processed to remove salts. Sources of liquids for desalination were primarily laundry wastes, non-radioactive production wastes, radioactively decontaminated waste, and chemically contaminated solutions from asphalt-lined ponds.

The original process waste lines are a network of tanks and underground pipelines used to transport and provide temporary storage for aqueous chemical and radioactive process wastes from point of origin to on site treatment and discharge. The original process waste lines consist of approximately 35,000 feet of pipeline, and seventy-three tanks in thirty-four separate locations. The system handled process wastes from Buildings 123, 444, 707, 771, 776, 779, 865, 881, 881, and 889, including minor amounts of process wastes from Buildings 122 and 441. The original process waste lines routed wastes to Building 774 or to one of the ponds used for either storage or solar evaporation.

These pipelines vary in age, use, and construction materials. They range from 1" to 10" in diameter, and are constructed of a variety of materials, including cast iron, stainless steel, vitrified clay, polyvinyl chloride, Teflon, plastic, and Pyrex glass. Construction of the original process waste lines began in 1952; additions, repairs, and maintenance on the system continued until 1975. Beginning in 1975, construction of replacement waste process lines began, and continued until 1984, when a new double-lined, fully inspectable system was completed.

Solid Waste Treatment

Two buildings were primarily responsible for the treatment of solid waste: Building 776/777 after the fire of 1969; and Building 889, a decontamination facility situated outside the Protected Area. Only Building 776/777 was considered part of the historic district.

Building 776/777 was the main production facility for weapons components until the 1969 fire. Waste operations began in 1969 and were initiated as a means to systematically dispose of fire-damaged equipment.

Building 889 was an equipment decontamination and waste reduction facility for equipment and wastes. Waste materials included surplus equipment, high efficiency particulate air filters, and combustible materials (e.g., paper and plastic) generated inside process areas requiring personal protective equipment for entry, and decontamination prior to exit. Surplus equipment was evaluated for future use; decontaminated equipment might have been reused on site or sold off site. Equipment used included a compactor, a drum crusher, a steam cleaner, and tools required for cutting and disassembly.

The original solid waste landfill at the Plant was located on the south side of the property. The landfill, which opened in 1952 and closed in August 1968, received non-radioactive solid waste such as paper, food items, office wastes, lumber, etc. An incinerator, Facility 209, located on the west access road, was also in operation from 1952 to 1958. The incinerator was used to burn non-radioactive combustible wastes. Resulting ash residue was buried next to the incinerator. The incinerator was demolished in the 1960s. A second sanitary landfill began operation in 1968. The second landfill was located on 25 acres north of the Plant in the buffer zone. The landfill was established to dispose of solid sanitary waste generated at the Plant, including dried sanitary waste sludge. By 1971, all solid waste originating in plutonium handling areas of the Plant was monitored for radioactivity prior to placement in solid waste dumpsters destined for the landfill.

Sanitary Wastewater Treatment

Liquid sanitary wastes consisted of sewage from restrooms and janitor sinks, water from showers, food processing areas, and cooling towers. The sanitary wastes from non-plutonium areas were kept separate from sanitary wastes from plutonium areas until they reached a diversion box upstream of two holding tanks above the sewage treatment facility, Building 995. At the holding tanks, the sewage was retained if it was suspected of being contaminated.

The Building 995 treatment process was a flow-equalized, two-train, continuous-flow, activated sludge system followed by polymer/alum-enhanced, post-secondary clarification, filtration, chlorination, and dechlorination. Trucking support was required to transfer the sewage from the wind energy research station and guard station to Building 995, and for the transfer of sewage sludge to the 910 drying beds.

The sanitary waste liquids were filtered and chemically treated. The filtered liquid flowed into the clear well and the first and second chlorine basins for disinfecting. From the second chlorine basin, the treated water went into Pond B-1, then to Pond B-3, and finally to Pond B-4. Initially, treated effluent was discharged from Pond B-4 to Walnut Creek drainage. In 1979, a no discharge policy was instituted, resulting in the use of spray fields to evaporate treated wastewater. The spray fields were used from 1979 to 1985. Treated effluent was also evaporated in Building 374.

Treated wastewater was pumped to the cooling towers of production buildings and evaporated. As the cooling tower evaporated the wastewater, the dissolved and suspended solids remained in the circulating water and would eventually reach a level detrimental to cooling tower operation. Various chemicals are added to the cooling tower's circulating water systems to prevent biological growth, corrosion, scaling, and other effects that can foul heat transfer surfaces and degrade performance. Proportional amounts of these chemicals and their reactants are carried with the blow-down water, which is discharged into the sanitary sewage system. Total solids in the cooling tower water are normally maintained at approximately 500 to 700 parts per million.

Solids from each stage of the liquid waste treatment (aerators, chemical mixing pit, final clarifier, catch basin, and filters) were routed back to the digester for retreatment. From the digester, solids were sent to drying beds, then packaged for offsite shipment.

A number of sludge drying beds had been in use throughout the operational history of the treatment plant. The three original beds were sand and gravel pads; more beds were added in 1962 and 1985. One of the 1985-installed beds was lined with concrete. In 1991, two beds previously used for reverse osmosis processes associated with Building 995 were converted for use as sanitary waste sludge drying beds.

Waste Storage

Rocky Flats had numerous structures, buildings, sheds, and pads for on site storage of waste, including the following:

- Building 569 was located within the Protected Area and was used for storage and radioactive assay of waste crates
- Building 664 was a waste storage, waste staging, and waste shipping facility;
- Building 788 functioned as a storage facility - previous uses included pondcrete processing, where sludges from nearby solar ponds were pumped into the facility and mixed with Portland cement;
- Building 964 stored low-level mixed waste and low-level waste in cargo containers; and
- The 750 and 904 storage pads, which are outside facilities, were originally used as parking lots for office trailers. In 1987, the pads were paved for use as storage areas

for pondcrete and saltcrete. In 1990, five tents were installed on the 750 pad and four tents on the 904 pad. The tents provided storage areas for pondcrete and saltcrete.

Utilities Systems

Water

Initially, water was brought in from the city of Boulder in tank trucks until the on site water treatment facility was operational (ChemRisk, 1992). Construction of the water system began in 1952, and was completed in 1953. The system has been operating daily since then, with no interruption in service (Web, 1997).

All raw water was purchased from the City and County of Denver and was drawn from two Denver-owned sources, Ralston Reservoir and the South Boulder Diversion Canal (Rockwell, 1989).

Originally, the primary year-round source of raw water was Ralston Reservoir. Completed in 1938, Ralston Reservoir is located about 5-1/2 pipeline miles south-southwest from the Plant site. The reservoir, with a capacity of 1,200-acre feet, originally provided about two-thirds of the water required by the Plant. It is filled from the drainage basin in which it lies and from Gross Reservoir, by way of the South Boulder Diversion Canal. Water was pumped from Ralston Reservoir to the Plant through a cast iron supply main (Denver Water Board, 1997; Web, 1997; Rockwell, 1989).

In the early 1980s, the South Boulder Diversion Canal, which passes about one and one-half miles west of the Plant, became the primary source of raw water at the Plant. The canal transfers water from Gross Reservoir to Ralston Reservoir. Because Gross Reservoir, located on South Boulder Creek about ten miles west-northwest of the Plant, is considerably larger and at a higher elevation than Ralston Reservoir, water was carried to the Plant by gravity flow. The Denver Water Board regulates the flow in the canal (Web, 1997; Rockwell, 1989).

Incoming water may be stored in the raw water storage pond located about 1/2 mile west of the water treatment plant (Building 124). The pond has a nominal capacity of 1.5 million gallons, enough water for approximately four days. If necessary, the pond could be bypassed and the water could be pumped directly to the Plant (Rockwell, 1989).

At the Plant, the incoming raw water was divided into two streams. One entered an on site raw water distribution system to disburse water for cooling towers and minor irrigation and miscellaneous purposes. The second stream passed through Building 124 where the water was treated and distributed for domestic, process, and fire protection uses throughout the Plant (Rockwell, 1989).

The potable water system at the Plant has over 2,000,000 gallons of storage capacity in four storage tanks and the Building 124 clear well. Building 215A was one of the storage tanks, and is the only elevated water tower on site. The storage was designed so two separate 4-hour sources of fire protection water were available at all times (Rockwell, 1989).

Filter backwash water from Building 124 was reprocessed in a facility that had two 60,000-gallon storage tanks, two drying beds, and several pumps. This facility permitted reuse of highly turbid water, eliminating its discharge off site (Rockwell, 1989).

Near Building 124, there is a connection where, in an extreme emergency, the incoming raw water main could be connected directly to the treated water distribution main, bypassing all storage tanks and the treatment plant.

Steam Distribution

Steam produced by boilers at Rocky Flats was used in the heating and air conditioning systems in the buildings and for process heating. Condensate from the heating, ventilation, and air conditioning systems Plant wide was returned to a 300,000 gallon tank (Facility 211), which is located near the steam plant, providing a reserve of boiler feed water. The condensate from process heating was also returned to the steam plant, unless it was contaminated, in which case it was sent to waste treatment for processing.

Building 443, the steam plant, was constructed in 1952, and brought on line in 1953. The building's exterior walls are constructed of concrete and metal. Metal wall additions were constructed in 1966, 1970, 1974, and 1982 to house additional or replacement boilers. The original steam plant main space and mezzanine occupied 4,004 square feet. The 1966 addition encompasses 6,810 square feet on the main floor and mezzanine; the 1970 addition occupies 4,422 square feet on the main and mezzanine floors; and the 1974 addition consists of 4,618 square feet on the main and mezzanine floors. A locomotive was brought on site to provide steam for building heat prior to completion of the Steam Plant (ChemRisk, 1992).

The steam plant originally housed boilers 1, 2, and 3, which were fueled with No. 6 fuel oil. Fuel oil was stored in two aboveground fixed roof storage tanks with a combined capacity of 2.3 million gallons. The Plant converted to natural gas in 1966 with the removal of the original three boilers and installation of boilers 4 and 5. In 1970, boiler 6 was installed. Boiler 7 was installed in 1974. In 1982, a utility upgrade resulted in the final addition to the steam plant with the construction of a co-generation building.

Steam distribution lines are both above and below ground. The major underground lines in the system are a 12" line from Building 443 to a valve pit near Eighth Street and Central Avenue. The major overhead line runs from Building 443 to the plutonium recovery and waste treatment facilities, Buildings 371 and 374. The remainder of the Plant was served by a 125-pound-per-square-inch system, most of it overhead, from Building 443.

The steam plant was equipped with an emergency generator backup system able to prevent boiler shutdown during power outages by providing all four boilers with a continuous power supply. One generator also provided emergency power for the fire station part of Building 331. The generators were divided so that each one could support two boilers through automatic transfer switches at their respective motor control centers.

Supplemental, standby steam boilers were located in Buildings 881 and 771 for use should the main steam plant shut down. Building 991 was equipped with supplemental hot water boilers. The supplemental boilers were for heating purposes only, and were not used for production.

Plant Power

Plant electricity was purchased from Public Service Company of Colorado. The Plant did not produce its own power for production purposes.

Maintenance

The maintenance structures considered contributing elements to the overall significance of the Rocky Flats Plant included Buildings 333 and 334. Building 333 is a one story, concrete block building. The building is approximately 30' x 100', outside dimensions. Building 333 was originally constructed in 1953; later additions were completed in 1967 and 1973.

Paint storage and painting operations occurred in Rooms 101, 102, and 102A of Building 333. Sandblasting was performed in Room 103 with support equipment in Room 104 and external to the building. The balance of the building housed offices and building support (restrooms, janitor closets). To the west exterior, there was free standing sandblasting equipment with metal frame support for separating paint residue from the blasting agent. There was also a small concrete block storage shed and temporary metal cargo containers.

Building 333 had specialized heating, ventilation, and air conditioning systems for venting of spray paint fumes and the sandblaster. Three specialized off-gas cleanup and filtering systems were installed: a very large filter system for the Room 102A spray booth; a smaller filter system for the Room 101 spray hood; and a cyclone and filter system for the sandblaster to the west end of the building, outside Room 104.

Building 334 primarily supported site maintenance activities and included electrical, machine, sheet metal, carpentry, and pipe shops. Building 334 also had an office area and housed the credit union. Building 334 has a two story shop area and single story office wing and contains approximately 40,000 square feet of space. The exterior walls are constructed of concrete/steel, concrete block, and transite. Some of the exterior walls of the shop area have windows that have been painted.

The Employees

Throughout the years, the Rocky Flats Plant contractors offered jobs to people. In 1951, the Plant employed about 133 people (excluding construction workers). In 1953, when production at the Plant began, the number had risen to 1,059 employees. In 1957, the Soviet Union launched Sputnik and sent the United States into a panic. The Soviet Union had been perceived to be ten years behind the United States in technological developments, but after the launch it appeared they were five to seven years ahead. The government pressured the weapons complex contractors to increase the stockpile of weapons (Tesitor, 1998 interview). From 1957 to the end of the first expansion of the Plant in 1963, the number of employees grew to over 3,000.

In the 1960s, the Atomic Energy Commission changed to a single mission policy, the Plant became the sole producer of triggers, and the employee population rose to over 3,700 by 1970. During the mid-1970s, the Plant had finished the production for prior weapons programs and was awaiting the startup of new ones. Some Plant employees felt that President Jimmy Carter was reluctant to authorize the enhanced-radiation weapon, which was designed to kill people as well as destroy property (Wilson, 1998 interview). Dow Chemical did not renew their contract as site operator. The Plant employee population slid to around 2,750; below the employment level in 1963. The Plant stabilized employment levels with new work in non-nuclear weapons production in stainless steel and depleted uranium armor (Tesitor, 1998 interview).

Under Rockwell and President Ronald Reagan's administration in the 1980s, the Plant population grew again, reaching close to 6,000 employees. When production was curtailed in 1989, many outside contractors were brought in to bring the buildings up to current standards and write operational procedures so that production could resume.

During 1991, the Plant population had increased to over 7,100 employees. Until 1989, slightly over half of the population had been hourly (union) laborers, with the balance being salaried. Under EG&G, hourly (union) laborers accounted for about one-third of the work force. During the early production years, the Atomic Energy Commission had a low level of representation on site (five employees in 1961). After production ceased, the USDOE and support staff population represented over 200 people (Kaiser-Hill Human Resources records, n.d.).

The Rocky Flats Plant offered steady work and good wages. Many production laborers started as janitors, cleaning up contamination, emptying trash, and mopping the floors; a position that paid better than a semi-skilled labor position outside the Plant (interview, 1997). In the early 1960s, a janitorial position off site paid approximately $2.00 per hour, compared to $6.00 per hour at the Plant (Tesitor, 1998 interview). Most stayed in a janitorial position for a month or two, while internally competing for a production line or other position.

In July of 1956, Atomic Energy Commission's 20th semi-annual report identified Rocky Flats as a "weapons production facility," with no further explanation of the Plant's secret function. The use of plutonium at the Plant was not reported officially until June 16, 1957 by *The Denver Post*. The article came out as a result of reports that two workers had been injured in an explosion at the Plant on June 14, 1957. Also in a 1957 press release, the Atomic Energy Commission stated that plutonium was kept at the Rocky Flats Plant (Buffer, 1997 interview). In November of 1960, the first aerial photograph of Rocky Flats was published in *The Denver Post*. The caption for the article stated that, "Little is known about the Plant's work, except that it handles radioactive materials and some of the very rare minerals coming into new prominence in the defense program" (*The Denver Post*, 30 Nov 1960). There is no record of when the public was officially informed of the specific products being manufactured at the Plant.

Very few employees knew what the final product was that was being shipped to Pantex (Weaver, 1998 interview). Most of the employees did not consider it important to know what the final product of the Plant was. What the workers did know was that whatever they were doing was important to national security and they believed their work was keeping communism from the United States' shores (Riddle, 1997 interview). A year or so into a job, many employees were able to deduce the true nature of their work. Although some may have been opposed to nuclear weapons in general, most supported a strong government to deter the use of these weapons by others (Wilson, 1998 interview).

Dow promised job security, and that the workers could work there until they retired. Benefits were impressive – vacation, insurance, sick leave, and retirement. The contractor provided clothes, physical examinations, and a hot meal at a very low price.

The work was interesting, the facility was safe, and the pay was better than most. Opportunities to move up were ample, and Dow Chemical was running the Plant satisfactorily and had good relations with the labor union (Riddle, 1997 interview). Some employees would choose the night shift so they could finish school or spend time with their family (Weaver, 1998 interview; Riddle, 1997 interview). Dow was interested in keeping their employees. The expertise and talent needed to run such a facility could not be hired off the street, and it was a one-of-a-kind plant (Tesitor, 1998 interview). In July of 1974, in recognition of superior performance in safety, environmental control, production, and energy use reduction, Dow employees at Rocky Flats were each paid cash awards equivalent to six and one-half percent of their 1973 base pay (totaling more than $2,280,000).

Despite the rapid pace that weapons production facilities went up across the country in the early 1950s, the Plant was well organized and operated in a safety conscious manner. Most of the training was on-the-job. Knowledgeable people taught new people. Written procedures were minimal. Written procedures that were available were considered guidance, and could not substitute for the feel for the job acquired by the operators (Weaver, 1998 interview). Complex processes relied as much on the operators' first-hand knowledge of the system as on their knowledge of formulas or a procedure. The buildings were in good condition, the floors were polished, and even the desks were polished once a month (Wilson, 1998 interview).

The opportunity to work with cutting edge technologies led to many patents and attracted people with advanced degrees to the Plant (Cunningham, 1998 interview). In 1987, ninety-six employees with Ph.D.'s worked on site, a large number for a non-academic setting (Meyer, 1998 interview). Production and laboratory staff got what they needed to do their work. If a tool was required for a specific task, it was made available. In many cases, there were no commercial products available. Machine shops and the machinists on site were top-notch; they would fabricate whatever was needed to facilitate a project.

Employees working at Rocky Flats, were leaders in the field, knew the latest techniques, and what could and could not be done (Richey, 1998 interview). Early on, there were very few locations in the United States that had the capabilities to work with plutonium. The study of the behavior and properties of plutonium was wide open. Very few people were doing it, and to those in research and development at the Plant, it was very exciting (Stakebake, 1998 interview).

Rocky Flats was a high-security facility. Interviewees and employees knew that the facility was run by the Atomic Energy Commission, and that the Plant was engaged in weapons production. Secrecy was an everyday part of working at the Plant. Even spouses and children were kept in the dark regarding the materials used at the site.

Although secrecy and need-to-know were key security strategies, gossip and comradeship flourished on site. If a co-worker sustained an injury, got a security infraction, or there was a death in the family, the site population knew of it in a very short period of time. Money was collected or good natured ribbing ensued almost immediately. The employees had a strong sense of mission and goal. As one employee put it, "we were helping to fight communism, it was as all American as you could get" (Cunningham, 1998 interview).

A Rocky Flats Family Day was held May 2-3, 1970. This was the first opportunity in the Plant's nineteen years of operation for families to see the facility. Approximately 7,700 people attended the event, including invited members of the press. During the August 26, 1972 Rocky Flats Family Day Celebration, several buildings were opened for viewing, including manufacturing facilities in Buildings 776/777 and 444, research facilities in Building 991, the library in Building 706, and the ceramics laboratory in Building 750 (USDOE Public Affairs, n.d.).

When Rockwell International took over operation of the Plant on July 1, 1975, Plant management began conducting regular briefings to the local press. By July 18, 1975, Rockwell began the first regularly scheduled public tours of the Plant, along with publishing the *Rockwell News*, a four-page employee newspaper published every other Friday.

The Plant mission change in 1992 from weapons production to environmental cleanup had the greatest impact on the employees. Few believed that the Cold War would ever end. After more than thirty years of working in a cutting-edge field and developing highly specialized components, there was no market for this kind of expertise (Tesitor, 1998 interview). The work that many had spent their entire careers doing, ceased. One employee put it this way: "the mission was gone and there is no glory or grace in clean-up" (Cunningham, 1998 interview).

<u>Future of Rocky Flats</u>

With the collapse of the Soviet Union in 1991 and the end of the Cold War nuclear arms race, USDOE's emphasis at Rocky Flats shifted from weapons production to waste management, stabilization, and clean-up activities. This transition involved both engineering and institutional changes.

Rocky Flats goals that are currently being addressed include: stabilization of radioactive materials; disposal of clean up wastes; and development of new technologies to handle environmental clean-up.

The key to an atomic weapon is the fissile material. The triggers manufactured at Rocky Flats contained the majority of fissile material found in a nuclear weapon. With the retirement of the weapons program, the primary function of Rocky Flats, production of the trigger components, was no longer considered essential.

At this writing, all buildings associated with plutonium production or use of plutonium at Rocky Flats are to be closed down and removed. Facilities identified for total closure include Mound, Pinellas, Fernald, Hanford, and Rocky Flats. Other facilities will continue to operate in research and development, storage, and/or fabrication.

The cleanup strategy for Rocky Flats is outlined in the 1998 draft document *Accelerating Cleanup: Path to Closure Rocky Flats Environmental Technology Site.* The end state for the Plant has not been finalized, however, the Rocky Flats Closure Agreement describes an end state in which:

- All special nuclear materials are shipped to an off site repository;
- All radioactive waste is shipped off site;
- All facilities are demolished except for facilities contracted for commercial reuse;
- Environmental remediation of contaminated areas is complete to the extent that future land uses are enabled and downstream water supplies are protected; and
- Land use enabled by cleanup levels would permit open space uses of the Plant's buffer zone and either open space or industrial reuse of the industrial area. The nature of open space has yet to be determined.

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